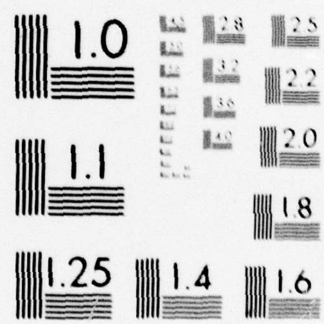
AD-A077 449 COAST GUARD RESEARCH AND DEVELOPMENT NTER GROTON CT F/G 13/10
AIR CUSHION VEHICLE (ACV) ICEBREAKER ST AND EVALUATION PROGRA--ETC(U)
AUG 78 J BUCK , B DENNIS , J ANTHONY E NEAL

UNCLASSIFIED CGR/DC-13/78 USCG -22-79 NL

1 OF 2

AD
A077449



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

AD A077449

19 (18) USCG

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
[redacted]D-22-79		

4. Title and Subtitle
Air Cushion Vehicle (ACV) Icebreaker Test and Evaluation Program. Volume 2. Operational and Engineering Analysis. (6)

5. Report Date
(11) Aug[redacted]78

6. Performing Organization Code

7. Author(s)
(10) J. Buck, B. Dennis, J. Anthony, E. Neal

8. Performing Organization Report No.
(14) CGR&DC-13/78

9. Performing Organization Name and Address
U.S. Coast Guard Research and Development Center
Avery Point
Groton, Connecticut 06340

10. Work Unit No. (TRAIS)

11. Contract or Grant No.

12. Sponsoring Agency Name and Address
Department of Transportation
U.S. Coast Guard
Office of Research and Development
Washington, D. C. 20590

13. Type of Report and Period Covered
(9) Final rept. 1977-1978

(12) 156

14. Sponsoring Agency Code

15. Supplementary Notes
This document is Volume 2 of a two-part report concerning ACV icebreaking operations conducted by the U.S. Coast Guard on the Illinois and Mississippi Rivers during the winter of 1977-1978.

16. Abstract

During the winter ice season, November 1977 through March 1978, the U.S. Coast Guard R&D Center, Avery Point, Connecticut, conducted an operational test program to evaluate air cushion vehicles as icebreakers. The vehicles used were the MACKACE ACV barge and the self-propelled LACV-30. Tests were conducted on the Illinois and Mississippi Rivers with operations centered around Peoria, Illinois. The MACKACE ACV was used solely to facilitate river commerce while the LACV-30 was used in this role and also for flood control purposes. Extensive operational tests were conducted which produced data concerning optimal icebreaking techniques and the effects of icebreaking on river commerce. Tests also established information on design criteria for ACV icebreakers, their maneuverability and control, operating costs and impact on Coast Guard personnel and facilities. As a result of the test program, significant advances were made in understanding ACV icebreaking procedures. The characteristics of ice were studied, and the necessity for developing ice classification and an icebreaking effectiveness methodology was identified.

AO77201

17. Key Words	18. Distribution Statement
Coast Guard, icebreaking, air cushion vehicle, river, towboat, barge ice-breaker, river commerce	Document is available to the public through National Technical Information Service, Springfield, VA 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
UNCLASSIFIED	UNCLASSIFIED		

Form DOT F 1700.7 (8-72) Reproduction of form and completed page is authorized

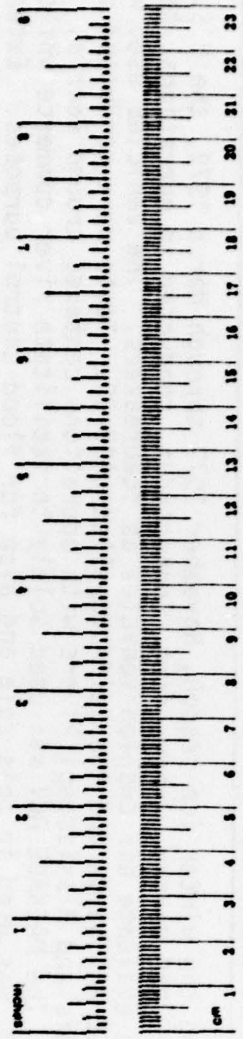
408 730 Gm

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

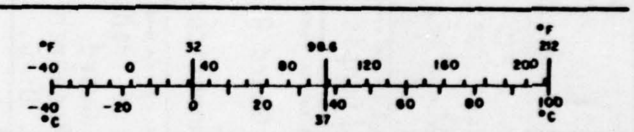
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



FOREWORD

The icebreaking operations conducted by the U.S. Coast Guard on the Illinois and Mississippi Rivers during the 1977-1978 winter season were designed to evaluate the applicability of air cushion vehicles as icebreakers in a river environment. Two air cushion vehicles were employed in this project, a nonself-propelled barge craft (RIVER GUARDIAN) and a self-propelled craft (LACV-30). It was not within the scope of the study to perform any comparative evaluation of icebreaking effectiveness between the two craft, and field operations were not designed for this purpose. The operational procedures for each craft have been discussed separately and results obtained have been explained under separate headings for clarity. Comparative data can only be developed through further research and evaluation involving the two craft.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGEMENTS

The technical direction and encouragement provided in this project by CDR Robert H. Cassis, Jr., of Coast Guard Headquarters Office of Research and Development and Messrs. Clark W. Pritchett and Robert E. Williams of the Coast Guard Research and Development Center are greatly appreciated.

In addition, the efforts of the following Commands and Organizations and their contributions to the test and evaluation are gratefully acknowledged:

Second Coast Guard District and participating units and commands

U.S. Army, MERADCOM, Fort Belvoir, Virginia

U.S. Army, Transportation School, Fort Eustis, Virginia

U.S. Army, CRREL, Hanover, New Hampshire

U.S. Army, Corps of Engineers, Chicago District and Peoria and Joliet project offices

ADMINISTRATIVE INFORMATION

In response to the Chief, Office of Operations, the Office of Research and Development (G-D) was assigned the responsibility of conducting a Test and Evaluation Program to determine the feasibility of using air cushion vehicles (ACV's) as icebreakers in a river ice environment (Reference 1). The Chief of Operations forwarded a task statement to the Chief, Office of Research and Development (Reference 2), who assigned the responsibility for developing the Test Plan, conducting the operational and engineering tests and preparing the final documentation to the Research and Development Center (Reference 3).

To carry out the ACV icebreaking operational/engineering test and evaluation program, two ACV craft, a nonself-propelled ACV barge and the self-propelled LACV-30, were obtained. The barge-type ACV was obtained under a lease contract from Mackley Ace (USA), Inc., for the period of 1 December 1977 to 28 February 1978 (Reference 4). The LACV-30 was obtained through the cooperation of the U.S. Army through a memorandum of understanding document for the approximate period of 15 November 1977 to 15 March 1978 (Reference 5).

Engineering support services were obtained by the Research and Development Center through a contract with the firm of Chi Associates, Inc., Arlington, Virginia, who employed as part of its team a subcontractor, Giannotti and Buck, Inc., Riverdale, Maryland (Reference 6).

The ACV icebreaking operational/engineering test and evaluation program was conducted on the Illinois and Mississippi Rivers with operations centered around Peoria, Illinois, in accordance with OPORDER CG 2-78. The operational base was the Coast Guard ANFAC (Aids to Navigation Facility) in

East Peoria within the Second Coast Guard District.

The following personnel were on site during the test and evaluation program:

- o Clark W. Pritchett, Project Manager, U.S. Coast Guard Research and Development Center
- o Lt. John Anthony, U.S. Coast Guard, LACV-30 Test Director, G-DOE-4
- o Orin Stark, SUMAC/ACV Test Director, U.S. Coast Guard Research and Development Center
- o CWO F.X. McCarthy, SUMAC/ACV Test Director, U.S. Coast Guard Research and Development Center
- o Jon Buck, Technical Engineering Support/Test Engineer, Giannotti and Buck, Inc.
- o Bernard Dennis, Technical Engineering Support/Test Engineer, Chi Associates, Inc.
- o CWO H. Sites, U.S. Coast Guard Research and Development Center
- o CWO George Matheson, U.S. Coast Guard, CGC SUMAC Commanding Officer
- o Crew of U.S. Coast Guard Cutter SUMAC
- o Major Lyle Haskins, U.S. Army, Commander of LACV-30
- o LACV-30 Crew and Support Group
- o Field Personnel from Mackley Ace, Inc.
  - Ray Golding, ACV Supervisor, 12-1-77 to 1-1-78
  - Alan Brice, ACV Supervisor, 1-1-78 to 3-8-78
  - John Latimer, Technical Engineer
  - Keith Jenman, Technical Engineer
- o Field visits were made by representatives of CRREL.

ODE TO THE HOVERCRAFT*

Hark, what is that mighty roar?
Rising, bellowing, more and more!
" 'Tis the Hovercraft," they shout,
"Here to break the ice and move it out."

O wonderful Hovercraft, save our trailers,
Show us all that we're not failures.
Break the ice and stir the waters.
Save our sons and save our daughters.

With multitudes upon the bank assembled,
The sky it darkened, the ground it trembled.
The ice broke up with crunching fury.
Hovercraft his own judge and jury.

O powerful Hovercraft, help us today.
Cleanse our souls and point out the way.
Break the ice and halt the flood.
Cleanse our houses of this mud.

Ice streaming off your bow and stern
You teach us lessons we never learn.
Ripping, punching, tearing through,
All hail to your able crew!

O terrible Hovercraft, don't let us down.
Bless us and keep us so we cannot drown.
Break the ice and stop this madness,
End the sorrow, cure the sadness.

Fracture, rupture, destroy that glaze,
Hammer and shred to earn our praise.
You floating, flying, savage beast
Spitting ice cubes from between your teeth.

O mighty Hovercraft, you give us pause
While wreaking havoc on nature's laws.
Break the ice and display your wrath
To guide us on the righteous path.

We'll build you temples, mosques and ramps.
We'll fuel your engines and light your lamps.
We'll bed you down when day is done.
We'll worship you, your ghost and your son.

O holy Hovercraft, give us the word
As you swim like a fish or fly like a bird.
Break the ice and blow the devil
From our tawdry, ice bound level.

Billowing, streaking snow from all sides,
Groaning and heaving, the ice it abides.
All up and down this cursed river,
Salvation is what you deliver.

Omnipotent Hovercraft, you must go away
But we'll get on our knees, we'll stoop to pray.
Break the ice, and to you we will sing.
We beg and beseech you to return next spring.

- Herman Binkle

* The Free Press/Gardner Chronicle, Page 11, March 16, 1978

1.0 INTRODUCTION

This document is Volume II of a two-part report concerning ACV icebreaking operations conducted by the U.S. Coast Guard on the Illinois and Mississippi Rivers during the winter of 1977-1978. Volume I, The Executive Summary, presented a comprehensive description of key elements of the test program including an operational summary, results, conclusions and recommendations (Reference 7).

This volume contains detailed operational and engineering information on testing procedures, analysis and results. These data include findings directly related to requirements of the formal Test Plan (Reference 8) and additional information collected, which was outside the scope of the Test Plan but directly pertinent to project goals. Since the amount of data collected was so immense, it has not been possible to incorporate the entire daily operational logs or data forms from either ACV. These are, however, available as unpublished records through the U.S. Coast Guard Research and Development Center, Groton, Connecticut (References 9 and 10).

2.0 BACKGROUND

The U.S. Coast Guard is charged with providing domestic icebreaking services to satisfy the reasonable demands of commerce and to reduce the potential of flooding in the Great Lakes and on coastal and inland waterways. The severity of the 1976-1977 winter pointedly emphasized the potential consequences of a lack of icebreaking capability on the inland waterways and its subsequent impact on northern cities, industrial areas and on river commerce. Heavy river ice acutely affects the ability of towboats to transit the rivers. In ice, the number of barges pushed by tows is reduced and transit times are increased. Fuel consumption is much higher and the vessels are subject to damage from ice. The net results are delays in the delivery of needed goods and resources to northern areas, with the towboat transportation industry incurring higher costs which are eventually passed on to the consumer.

Conventional icebreakers require relatively large draft so their effectiveness is limited in shallow water. Although the Coast Guard has had vessels operating in the Mississippi River system for many years, they are primarily engaged in providing aids to navigation and are not effective in icebreaking operations because of their limited horsepower and non-ice-strengthened hulls. To overcome this deficiency several alternative measures of breaking ice were studied, and it was determined that air cushion vehicles showed promise of being effective in an icebreaking mode.

Air cushion vehicles of various configurations had been tested as icebreakers in Canada and were considered as possible candidates for the shallow or otherwise restricted waterways such as the U.S. inland waterway system.

Two basic ACV configurations were employed in the Canadian tests, nonself-propelled barges and self-propelled vehicles. Both achieved certain successful results, depending on their deployment and the ice environment.

While it was apparent that this new air cushion vehicle technology had potential for application in the Coast Guard's icebreaking programs, it was not clear what the limitations and capabilities of the vehicles were, nor what impact they would have in the areas of personnel, facilities and support services. To gain experience in some of these areas, the U.S. Coast Guard decided to conduct an Air Cushion Vehicle Icebreaker Test and Evaluation Program during the 1977-78 ice season.

Detailed plans for the project crystallized in the summer of 1977. In order to obtain operational ACV's within the short time available for the 1977-78 winter season, it was necessary to locate existing designs rather than design and build a craft for specific operational requirements. Initially, it was determined that a nonself-propelled barge type ACV could be obtained in a short time frame with greater certainty of delivery than the more complicated self-propelled type. After receiving and evaluating proposals, a barge-type ACV was leased from Mackley Ace (USA), Inc. Later, the U.S. Army agreed to make available, in a joint Army/Coast Guard effort, a LACV-30 (Lighter Air Cushion Vehicle-30-Ton Payload) self-propelled craft complete with crew and support personnel (two officers and 13 enlisted men) and support equipment.

Because the MACKACE ACV was not self-propelled, it had to be pushed through the ice. The towboat assigned this task was the CGC SUMAC (WLR-311), which offered the advantage of pushing the ACV barge with a Coast Guard vessel whose capability was known. The SUMAC is the most powerful inland

river buoy tender in the Coast Guard inventory and its hull was specially ice-strengthened for this project.

The Mackley Ace (USA), Inc. contract was awarded on 31 August 1977, and the firm subcontracted to Alberici Construction Co. of St. Louis for fabrication and assembly of the craft's components. Some of the ACV components were shipped from England, while others were purchased in the United States. The assembly of the ACV components was conducted on the bank of the Mississippi River at mile 185.6. The Coast Guard took delivery in St. Louis on 30 November 1977 and named the craft RIVER GUARDIAN.

Since the Coast Guard desired to demonstrate and evaluate the potential of ACV icebreakers, it was necessary that emphasis be placed on operational testing more than upon engineering and technical development. As a result, the Test Plan developed for the program was primarily structured to collect descriptive operational data. Some hard engineering data were obtained by incorporating engineering measurements into as many operational tests as possible.

Operational tests were conducted from 1 December 1977 to 20 March 1978. Over 450 hours of icebreaking tests were conducted using the two ACV craft during that time. The craft were used to facilitate towboat traffic by operating in the river channel. In addition, the LACV-30 successfully demonstrated its versatility by performing flood control icebreaking on a tributary river (the Kankakee).

3.0 VEHICLE DESCRIPTION

Basically, an air cushion vehicle is a craft whose weight is supported by a cushion of air which is supplied by lift fans. The air cushion is formed under the craft by a flexible rubber-coated fabric skirt system. An ACV may either be a nonself-propelled lift platform, i.e., barge-type, or it may have an active propulsion system and thus be self-propelled.

The RIVER GUARDIAN was a nonself-propelled steel barge-type ACV, simply designed and built according to conventional boat construction techniques. Lift was obtained from two standard-type diesel engines which drove two centrifugal fans. The speed of the RIVER GUARDIAN was limited to that of its pusher vessel. Figures 3-1a and 3-1b give the general characteristics of the RIVER GUARDIAN.

The LACV-30 (Lighter, Amphibious, Air Cushion 30-Ton Payload) is a fully amphibious, high speed craft, designed for transporting military cargo payloads in the 25- to 30-ton capacity. The LACV-30 is powered by two twin-pack gas turbine engines rated at 1800 maximum shaft horsepower each. Lift capability is provided by two 7-foot centrifugal, 12-blace, fixed pitch fans. Propulsion capability is provided by two 9-foot, 3-blade variable pitch propellers, and it can attain speeds in excess of 40 knots. It is constructed of hollow core marine aluminum using aerospace technology. Figure 3-2 gives the general characteristics of the LACV-30.

The U.S. Coast Guard Cutter SUMAC (WLR-311) stationed in the Second District is the largest Coast Guard inland river buoy tender. For most river operations, the vessel is capable of operating at speeds up to 10 mph. However, its speed is drastically reduced in ice-clogged waters. For its role in pushing the RIVER GUARDIAN, the SUMAC's hull was modified by the addition of ice deflectors to protect the keel coolers, rudders and propellers. Figure 3-3 gives the general characteristics of the SUMAC.

GENERAL CHARACTERISTICS

- GENERAL DIMENSIONS 45 FT. x 55 FT.
- TWO GENERAL MOTORS DIESEL ENGINES 600 HP EACH (MODEL 16 V 71-N, 2100 RPM)
- TWO ALLDAY & PEACOCK CENTRIFUGAL FANS SINGLE INLET, FLOW RATE : 4800 CFM EACH (1200 B.A. SISW, DESIGN RPM = 2000)
- TWO 1000 GALLON FUEL TANKS
- HOVER HEIGHT BETWEEN 4 FT. & 5 FT.
- CUSHION PRESSURE MAINTAINED BETWEEN 0.95 PSI & 1.3 PSI (DEPENDING ON BALLAST)

IDENTIFICATION TABLE

1. BOW RUNNING LIGHT
2. ENGINE #1 EXHAUST
3. ENGINE #1
4. FAN #1
5. STEPS TO OBSERVATION DECK & CONTROL CABIN
6. STORAGE AREA
7. GENERATOR
8. PUSHING PAD
9. DECK FLOOD LIGHTS
10. CONTROL CABIN
11. SPRAY SUPPRESSION SKIRT
12. FINGER SEGMENTS OF SKIRT SYSTEM

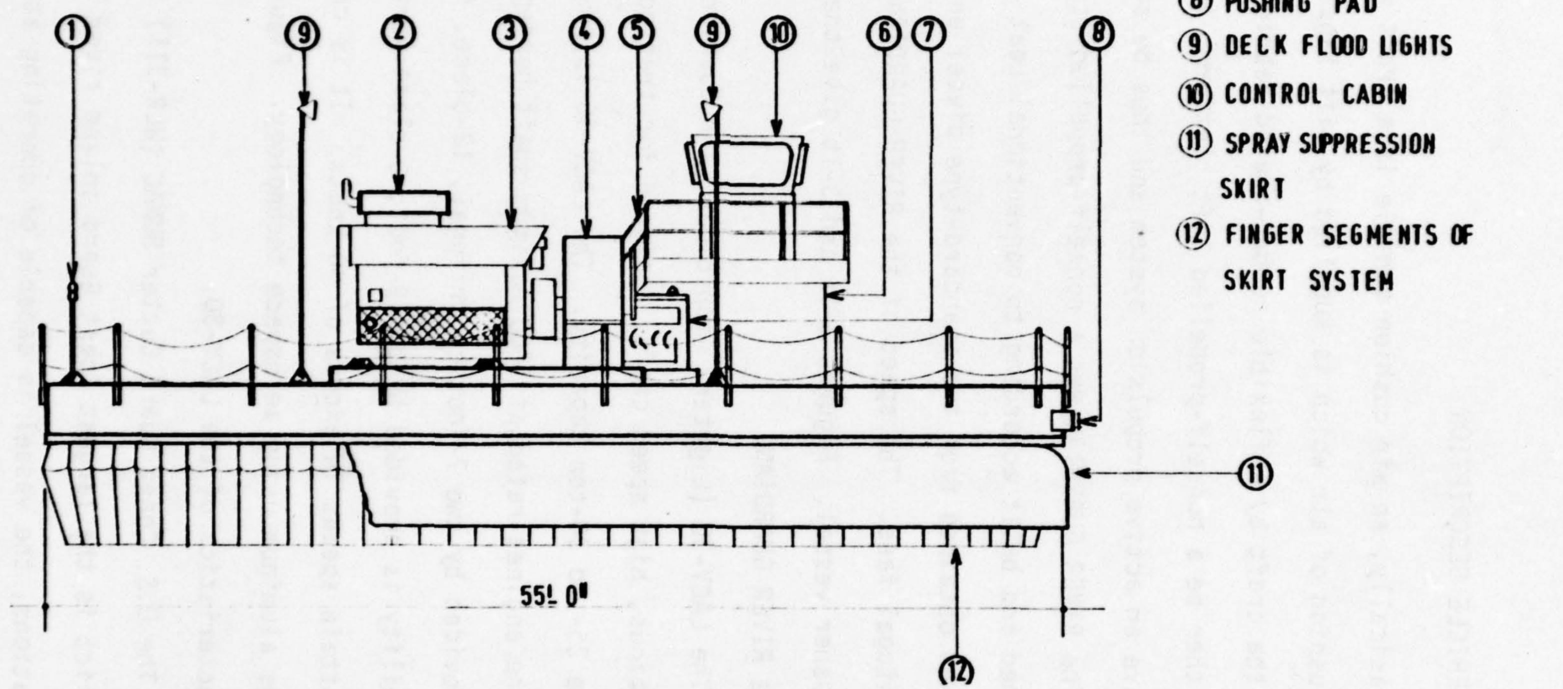
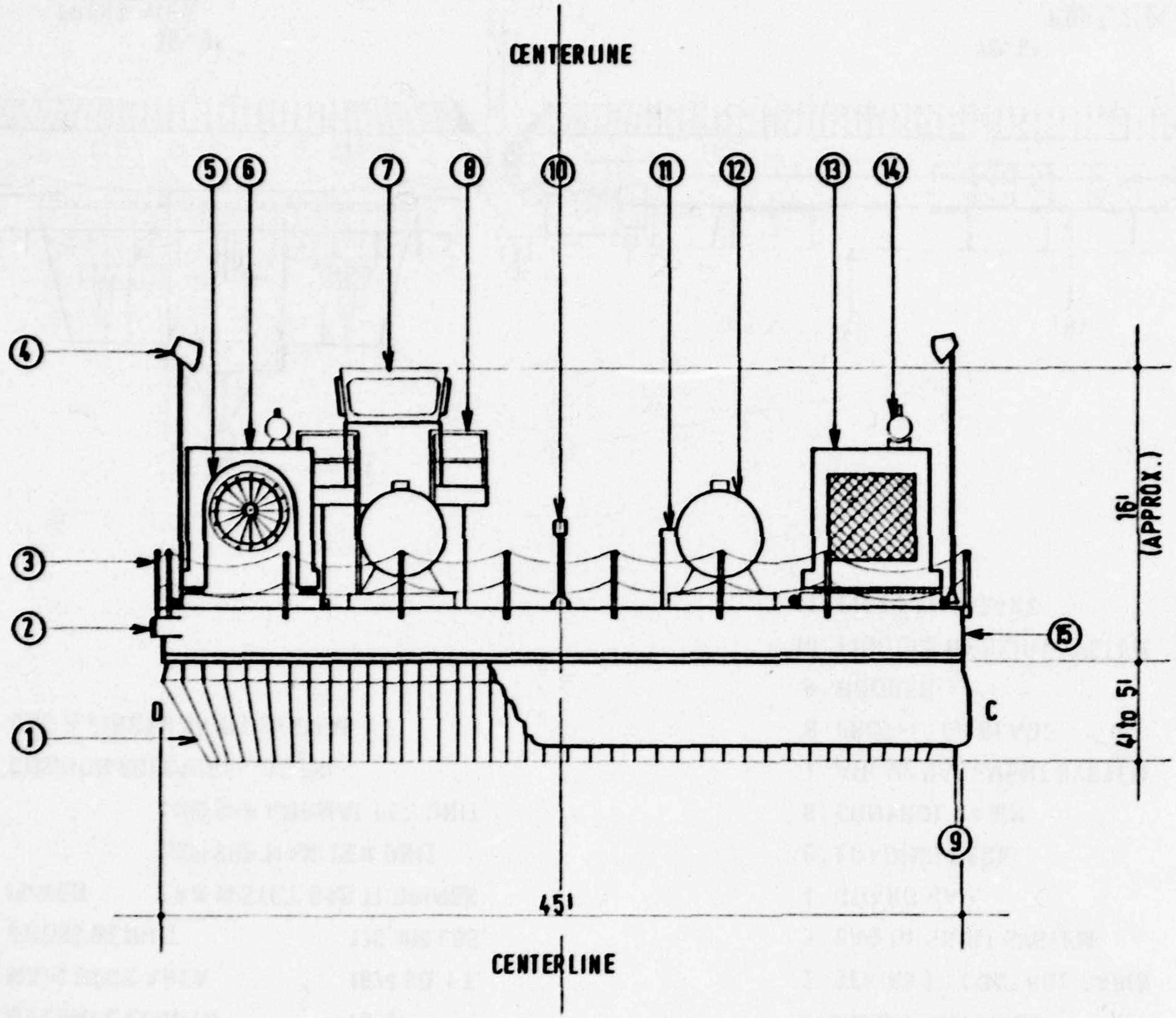


Figure 3-1a. River Guardian Profile, Side B-C
(NOTE : SPRAY SKIRT CUT BACK TO REVEAL SEGMENTS)



IDENTIFICATION TABLE:

1. SKIRT SEGMENTS
2. PUSHING PAD
3. GUARD RAIL
4. FLOOD LAMP
5. FAN # 2
6. ENGINE # 2
7. CONTROL CABIN
8. OBSERVATION DECK
9. SPRAY SKIRT
10. BOW RUNNING LIGHT
11. GENERATOR
12. FUEL TANK # 1
13. ENGINE # 1
14. ENGINE EXHAUST
15. PLENUM STRUCTURE

Figure 3-1b. River Guardian Profile, Side C-D

(NOTE: SPRAY SKIRT CUT BACK TO REVEAL SEGMENTS.)

GENERAL CHARACTERISTICS

- OVERALL LENGTH 76'-6"
- MAIN DECK AREA 1674 SQ. FT.
- GROSS WEIGHT 125,000 LBS.
- POWER 2 P & W STGT GAS TURBINES
  1800 SHP MAX. PER UNIT
  1400 SHP NORMAL PER UNIT
- CUSHION PRESSURE 0.5 PSI
- BAG & FINGER SKIRT SYSTEM

IDENTIFICATION TABLE:

1 RADAR ANTENNA
2 STAIRS TO CONTROL CABIN
3 BAG OF SKIRT SYSTEM
4 GUARD RAIL
5 LOADING DECK
6 CONTROL CABIN
7 AIR MANAGEMENT SYSTEM
8 PROPELLER BLADE
9 RUDDER
10 FINGERS OF SKIRT SYSTEM
11 LIFT FAN INTAKE

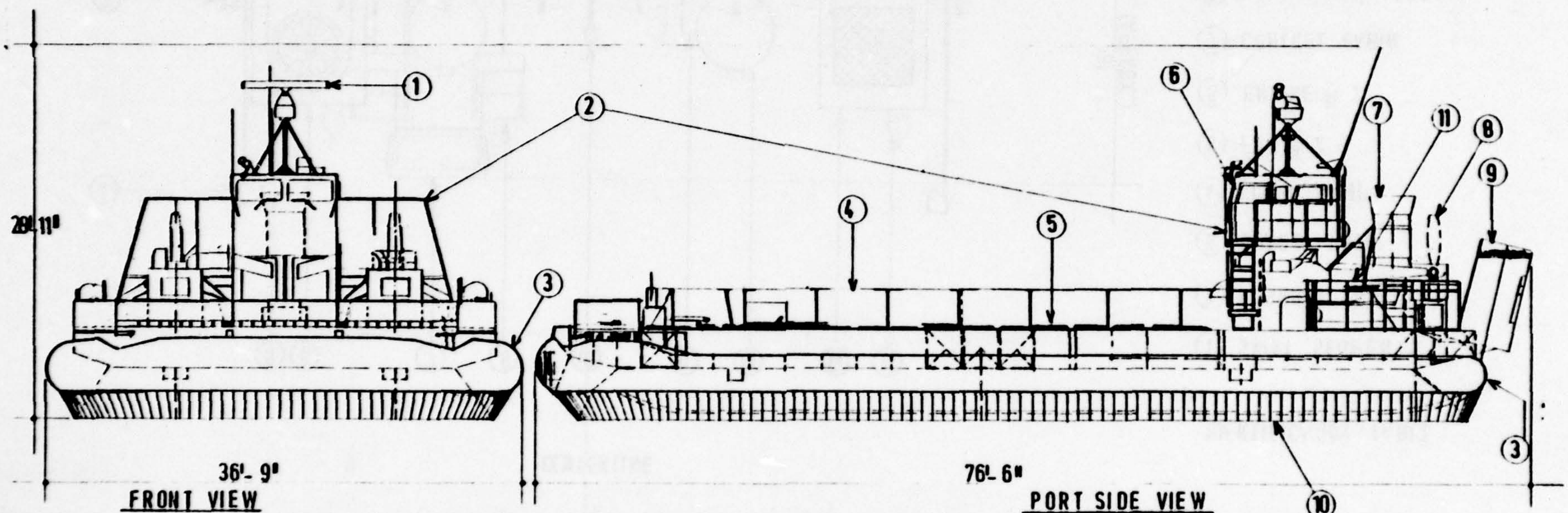


Figure 3-2: LACV-30 General Dimensions

GENERAL CHARACTERISTICS

• OVERALL LENGTH	114'-6"
• LENGTH BETWEEN PERPENDICULARS	108'-6"
• BEAM (EXTREME)	30'-3"
• DEPTH (MOLDED TO MAIN DECK)	10'-0"
• DRAFT MEAN (FULL LOAD)	7'-0"
• DISPLACEMENT (FULL LOAD)	390 S. TONS
• THREE DIESEL ENGINES	800 SHP MAX./UNIT

IDENTIFICATION TABLE

1 RADAR ANTENNA
2 SEARCH LIGHT
3 BRIDGE
4 "SPUD" ANCHORS
5 PUSHING KNEES
6 9" "V" SHAPED ICE DEFLECTORS BETWEEN KEEL COOLERS
7 8" ICE FENCE DEFLECTOR PLATES FOR SIDES OF KEEL COOLERS
8 9" "V" SHAPED ICE DEFLECTOR
9 14" ICE KNIFE (1 OF 6)
10 FLANKING RUDDER (1 OF 4)
11 PROPELLER
12 RUDDER (1 OF 3)
13 LIFE BOAT
14 LIFEBOAT CRANE

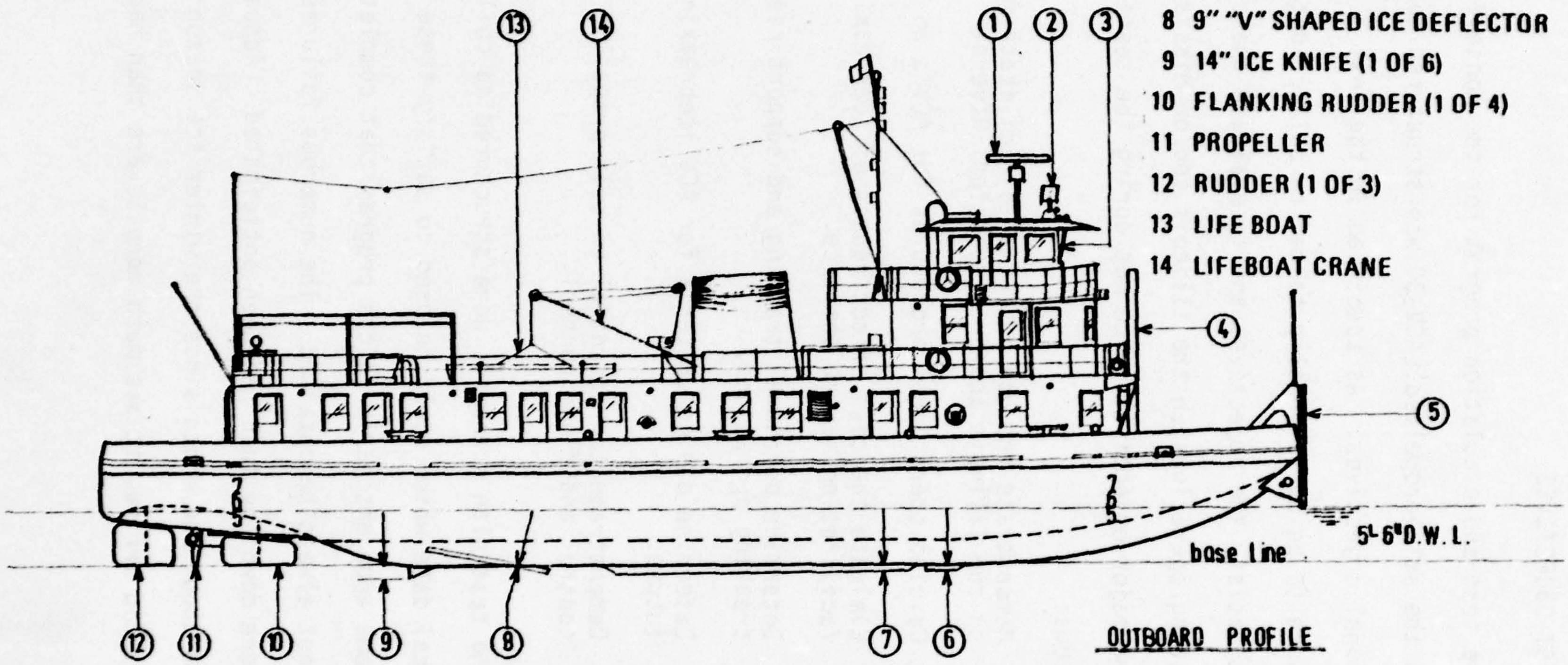


Figure 3-3: United States Coast Guard Cutter-Sumac

4.0 TEST OBJECTIVES

The test and evaulation program for the nonself-propelled MACKACE ACV and the self-propelled LACV-30 was structured to meet specific operational objectives. As specified in the Test Plan (Reference 8) the ACV's were to be operationally tested to collect data which were necessary to both satisfy the objectives and to evaluate the craft's suitability for icebreaking operations on the Illinois and/or Mississippi Rivers.

The major objectives to be met during the testing of the ACV's were as follows:

- Demonstrate the use of ACV's to facilitate marine transportation on the Illinois and/or Mississippi Rivers.
- Develop operational procedures for ACV's on western rivers.
- Evaluate the cost effectiveness of icebreaking ACV's in facilitating marine commerce.
- Determine personnel training and support needs for ACV icebreaking operations.
- Determine design criteria for ACV icebreaking operations in the future.
- Demonstrate the potential of self-propelled ACV's in ice jam control and flood control.

The test plan scenarios were structured to collect operational and technical data which would be used to satisfy these objectives. However, it became apparent early in the program that complete quantitative information could not always be obtained. The numerous failures on both craft necessitated much more downtime than had been anticipated. Actual ice operations were delayed about one month since the winter ice season was unusually late. When it did arrive, it was much more severe than had been expected and the

nature of the ice to be broken was much more complex than had been predicted. These heavy ice conditions affected the width and depth of the channel to which the SUMAC was restricted because of its size. In addition, conditions varied so widely from day to day that it was never possible to run identical tests on successive days with the same environmental parameters. Yet another problem was arranging for the availability of cranes and other support facilities to meet tight operational schedules. All of these factors combined to force modification or postponement of certain tests and, therefore, information necessary to meet the objectives is more complete for some than it is for others.

A Steering Committee was formed which met periodically in Peoria to redirect the priorities of the individual tests within the overall objectives of the test plan. In the end, little information was actually acquired on the cost effectiveness objective. Also, whereas training and support needs and design criteria were not addressed in depth, sufficient data was collected and subjective observations were made by experienced investigators to permit valid conclusions to be drawn and recommendations to be made.

5.0 OPERATIONAL SUMMARY

5.1 General

This section describes the operational aspects of the Test and Evaluation program, specifically identifying what data were collected and how they were collected. In addition, it presents a narrative account of the river ice environment and conditions encountered by the two ACV craft as they performed icebreaking tests.

5.2 Data Acquisition

A set of fourteen (14) specific tests were developed in the Test Plan. They are listed in Table 5-1. Individual test descriptions were initially developed for the nonself-propelled ACV and subsequently adapted to the self-propelled LACV-30. Nine data collection forms were used in collecting and recording the data during each test. A Test Integration Form was prepared for each test and was used to record each test parameter relative to the test time and river location baseline. Table 5-2 lists the data collection forms and test team members responsible for recording data collected during each test.

At the outset of the project, it became evident that there might be a problem in recording and correlating the data collected at [illegible]ious locations on the SUMAC and its ACV bow. To ensure proper data correlation and to establish a time and location baseline for test data integration, the testing operations were directed from the bridge of the SUMAC by the test director and/or test engineer. From this location, all the data gathering positions were coordinated by the use of the boat's communications system.

TEST NO.	TEST NAME	TEST PURPOSE
T-Ø1	Measure Commerce	To measure the elementary components of river commerce.
T-Ø2	Towboat Transit Measures	To determine the effect of air cushion vehicle icebreaking upon commercial towboat fuel consumption and transit times in ice.
T-Ø3	Towboat Maneuvering Measures	To determine the effect of air cushion vehicle icebreaking upon commercial towboat maneuvering in ice.
T-Ø4	Icebreaking Techniques	To learn the capabilities of the air cushion vehicle icebreaker to break ice under various operational conditions and constraints and to develop appropriate techniques for unique applications.
T-Ø5	Ice Pattern Documentation	To determine size and shape of the ice when broken by the air cushion vehicle icebreaker and determine the clearance (i.e., the width) of the track of broken ice.
T-Ø6	Passing Maneuver	To determine the characteristics of the air cushion vehicle icebreaker when passing a towboat.
T-Ø7	Stopping Maneuver	To study the relation between ice thickness and the stopping distance of the air cushion vehicle icebreaker following engine shut-down.
T-Ø8	Cost Effectiveness	To determine rate at which fuel is consumed and ice is broken for different combinations of ice thickness and speed.
T-Ø9	Impact on Coast Guard	To identify the needs for additional training and the types of personnel necessary to support an air cushion vehicle in the Coast Guard. Also to identify the additional hardware and/or support services necessary to maintain an air cushion vehicle.
T-Ø10	Design Criteria	To determine the technical aspects of air cushion vehicle design. This as a matter of course must include the performance of the pusher vessel also.
T-Ø11	Open Water Characteristics	To obtain engineering and operational information about the air cushion vehicle icebreaker when operating in open water.
T-Ø12	Turning Maneuver	To document the characteristics of the air cushion vehicle icebreaker in a standard turn in open water and ice.
T-Ø13	Icebreaking Maneuver	To observe and photograph ice breaking operations and study the physical mechanism by which the air cushion vehicle breaks ice.
T-Ø14	Ballasting	To trim and ballast the air cushion vehicle to desired values of cushion pressure and platform level.

Table 5-1 Fourteen Tests from the Test Plan

FORM	TITLE Test Description	RESPONSIBLE PARTY
F00	Test Integration Form	Test Coordinator (Support Engineer)
F01	Atmospheric Conditions	Support Engineer
F02	Ice and River Conditions	Support Engineer
F03	Operations	Support Engineer
F04	Engineering, Pusher	Support Engineer
F05	Engineering, ACV Bow	MACKACE Personnel
F06*	Maintenance, Support and Casualty	Support Engineer
F07*	Casualty Report	Support Engineer
F08*	Commerce	Support Engineer
NA	Ice Classification Sheets	Support Engineer
NA	Finger Segment Damage Diagrams	Support Engineer

*These forms were actually never used during the tests. Supporting contractor engineers recorded maintenance and damage reports separately as necessary. The finger segment failures were recorded on separately developed diagram sheets and commerce information was merely recorded informally as it was available.

Table 5-2 Test Form Responsibility

The locations coordinated and the data collected for each were:

SUMAC:

- o Deck - ice and weather conditions
- o Engine room - horsepower, fuel consumption, engine RPM
- o Bridge - time, location, speed, ACV cushion pressure, trim, maneuver type

RIVER GUARDIAN (ACV Bow):

- o Control cabin - trim, pitch, engine RPM, cushion pressure
- o Deck - ice conditions, hover height, icebreaking effects

From the bridge, the test director and test engineer established the data record by signifying at what times individual data items should be recorded. Thus, a data baseline relative to time, location, and ice environment was maintained.

Data gathering procedure on the LACV-30 was quite difficult due to space limitations and the fact that it was not possible to use the deck when the craft was underway because of heavy spray. Data were, therefore, recorded mostly from the cabin by the test director and engineer. This meant that measurements of ice conditions were actually estimates, except when the vessel was stopped and readings were taken from the deck.

5.3 Operations and Testing

In all, more than 57 tests were conducted and documented on the SUMAC/ACV and the LACV-30. Table 5-3 summarizes the tests conducted by the SUMAC/ACV. It should be noted, however, that many of the tests consisted of multiple runs and data points. Thirty-five multiple run tests were conducted which resulted in a total of 106 data items. The raw data for each test run are contained in Reference 9. An example of a data summary sheet is shown in Table 5-4a, b, c, d, and e.

TEST RUN TYPE		NO. OF TESTS	NO. OF RUNS
T01	Measure Commerce	1	1
T02	Towboat Transit Measures	Towboat Transit 5	7
T03	Towboat Maneuvering Measures		
T04	Icebreaking Techniques	8	38
T05	Ice Pattern Documentation	See Ice Classification	
T06	Passing Maneuver	1	1
T07	Stopping Maneuver	2	9
T08	Cost Effectiveness	Continually Monitored	
T09	Impact on Coast Guard		
T10	Design Criteria	10	35
T11	Open Water Characteristics	1	8
T12	Turning Maneuver	4	4
T13	Icebreaking Mechanism	See Ice Classification (Handled by Ice Classification System)	
T14	Ballasting	3	3
TOTAL*		35	106

* There were 35 formal tests conducted in accordance with the Test Plan. However, many tests included multiple runs, hence there were 106 runs in 35 tests.

Table 5-3 Summary of Tests Conducted by the SUMAC/ACV

DATE	T.C. NO.	RUN	SUMAC TOTAL H.P.	SUMAC AVG RPM	SUMAC FUEL GPH	SUMAC VEL. MPH	ACV RPM	ACV H.P.	ACV PRES. PSI	ACV AVG FUEL GPH	ICE CONDITIONS	COMMENTS	R.** S. F.
1977 12/29	001	1	580	900	34.4	8.9	TEST RUN WITHOUT ACV BOW				No ice, open water characteristics	Down bound travel	0
12/29	001	2	579	900	33.9	8	TEST RUN WITHOUT ACV BOW				No ice, open water characteristics	Up bound travel	0
12/29	001	3	793	1000	46.3	9.1	TEST RUN WITHOUT ACV BOW				No ice, open water characteristics	Down bound travel	0
12/29	001	5	1381	1200	84.2	10.4	TEST RUN WITHOUT ACV BOW				No ice, open water characteristics	Down bound travel	0
12/29	003	1	1067	1044	71.7	3.4	TEST RUN WITHOUT ACV BOW				Unconsolidated brash	Mostly pushing the ice, some breaking	7*
12/30	004	1	1015	1000	61	5	1600	--	0.94	30		Test measurements on ice incomplete	9*
1978 1/11	005	1	147	724	9	2.5	1800 1900	--	1.05	30		Tested on keel engine only	12*
1/11	005	5	1674	1132	98.1	2.8	1800	--	1.05	30	Refrozen brash up to 14 inches thick, avg. 6 to 8 inches consolidated	Up bound-only keel engine measurements were taken. Other engine values assumed the same	--
1/11	006	1	595	1140	35.4	3	NA	NA	NA	30	New solid ice	This test was run on keel engine only	11*
1/11	007	1	128	423	7.3	$\approx$2	1900	--	0.97	30	Ice had been previously broken	Down bound	--
1/14	008	3	1223	964	69.4	3.2	1800	--	1.04	30	Previously broken but consolidated ice $\approx$14 in. thick, ice chunks 10 to 15 ft. across knitted together with 4 to 6 in. ice, acted as large flow	Up bound	16*
1/14	008	5	1148	1003	67.8	$\approx$3.5	1800	--	1.04	30	Same as previous entry	Up bound	16*

* Estimated
** Relative Strength Factor

Table 5-4a Data Summary Sheet for Tests Conducted by the SUMAC/ACV

DATE	T.C. NO.	RUN	SUMAC TOTAL H.P.	SUMAC AVG RPM	SUMAC FUEL GPH	SUMAC VEL. MPH	ACV RPM	ACV H.P.	ACV PRES. PSI	ACV AVG FUEL GPH	ICE CONDITIONS	COMMENTS	R.** S. F.
1978 1/17	009	3	1746	1154	111.7	4.2	TEST	RUN WITHOUT	ACV	BOW	Refrozen brash chunks 8 to 12 inches thick, 4 to 10 ft. wide knitted with 2 in. of new ice	Up bound	12*
1/17	009	4	1895	1097	105.3	6.5	TEST	RUN WITHOUT	ACV	BOW	Data taken in channel narrow between lakes. Ice avg. 6 in. thick with some chunks 12 in. thick thin knitting ice < 1 in.	Runs 4 and 5 similar conditions up bound, ice previously broken by tows	12*
1/17	009	5	1671	1066	97.0	6.2	TEST	RUN WITHOUT	ACV	BOW			
1/17	009	6	1814	1135	106.5	7.5	TEST	RUN WITHOUT	ACV	BOW	Brash ice plates 4 to 10 ft. across 4 to 8 in. thick, chunk spacing 2 in to 2 ft. knitting ice ~1 in. thick	This ice appeared to be unconsolidated with only light ice binding it together	11*
1/17	009	8*	1818	1046	106.0	4.7	TEST	RUN WITHOUT	ACV	BOW	Refrozen brash chunks 8 to 12 inches thick, 4 to 10 ft. wide knitted with 2 in. of new ice	Down bound	12*
1/21	010	1	262	594	15.5	1.8	1800	--	1.06	30	Ice was solid covered with 2 inches of snow	Up bound, channel broken 70 ft. wide	16
1/21	010	2	262	580	15.4	1.6	1800	--	1.06	30	Ice was solid covered with 2 inches of snow	Up bound, channel broken 70 ft wide	16
1/21	010	3	839	908	34.5	3.8	1800	--	1.10	30	Ice was solid covered with 2 inches of snow	Up bound, cgannel broken 70 ft wide	18
1/23	011	2	1100	989	64.0	3.4	1750	--	1.03	30	This ice was very thick slush and hard to classify		13
1/23	011	3	1104	989	66.2	2.7	1750	--	0.91	30	Very thick packed ice		14
1/24	012	1	319	633	18.8	NA	TEST	RUN WITHOUT	ACV	BOW		Started into ice but stopped in 1½ boat lengths	15
1/24	012	2	1882	1180	110.8	NA	TEST	RUN WITHOUT	ACV	BOW		Started from dead in water bow into ice	15

* Estimated
** Relative Strength Factor

Table 5-4b Data Summary Sheet for Tests Conducted by the SUMAC/ACV

DATE	T.C. NO.	RUN	SUMAC TOTAL H.P.	SUMAC AVG RPM	SUMAC FUEL GPH	SUMAC VEL. MPH	ACV RPM	ACV H.P.	ACV PRES. PSI	ACV AVG FUEL GPH	ICE CONDITIONS	COMMENTS	R.** S. F.
1978 1/24	012	3	1955	1153	115.5	2.9	TEST	RUN	WITHOUT ACV	BOW		Data taken after running start	10
1/24	012	4	440	611	18.3	< 1	TEST	RUN	WITHOUT ACV	BOW		Data taken from a running start	14
1/24	012	5	1805	1115	112.8*	NA	TEST	RUN	WITHOUT ACV	BOW	Rafted up over 5 ft. thick	Came to a full stop	16
2/3	013	1	244	588	14.5	3.8	1650	NA	0.98	30	Unconsolidated brash 1 to 2 feet thick		10
2/3	013	2	240	579	13.8	3.4	1650	NA	0.98	30	Unconsolidated brash 1 foot thick		4
2/3	013	3	287	607	16.6	2.5	1650	NA	0.98	30	Unconsolidated brash 2 ft., imbedded chunks 10 ft.		8
2/4	014	1	241	581	14.2	3.6	1750	NA	0.99	30	Brash unconsolidated 2 ft. to 3 ft. thick		5
2/4	014	2	194	591	11.4	3.7	1750	NA	0.99	30	Brash unconsolidated 2 ft. to 3 ft. thick		5
2/4	014	3	239	581	14.2	3.5	1750	NA	0.99	30	Brash unconsolidated 2 ft. to 3 ft. thick imbedded chunks		11
2/4	014	4	857	921	50.3	3.1	1750	NA	0.99	30	Brash unconsolidated 2 ft. to 3 ft. thick imbedded chunks		12
2/4	014	5	521	783	30.4	3.4	1750	NA	0.98	30	Brash unconsolidated 2 ft. to 3 ft. thick ice balls 8 ft. thick		13
2/4	014	6	345	676	20.2	3.7	1800	NA	0.99	30		Down bound previous broke run #5	--
2/4	014	7	221	561	12.6	3.4	1800	NA	0.99	30		Down bound previous broke run #4	--
2/4	014	8	201	541	11.8	3.5	1800	NA	1.00	30		Down bound previous broke run #2	--

* Estimated
** Relative Strength Factor

Table 5-4c Data Summary Sheets for Tests Conducted by the SUMAC/ACV

DATE	T.C. NO.	RUN	SUMAC TOTAL H.P.	SUMAC AVG RPM	SUMAC FUEL GPH	SUMAC VEL. MPH	ACV RPM	ACV H.P.	ACV PRES. PSI	ACV AVG FUEL GPH	ICE CONDITIONS	COMMENTS	R.** S. F.
1978 2/6	016	1	255	579	14.8	2.4	1700	NA	NA	30	Plate ice broken into 3 ft. chunks		13
2/6	016	2	286	599	16.6	1.6	1700	NA	NA	30	Refrozen brash, Consolidated		14
2/6	016	3	585	851	39.2	3.6	1700	NA	1.01	30	Consolidated brash ≈ 4 inches thick		13
2/6	016	4	316	641	18.6	2.6	1700	NA	1.03	30	Consolidated brash ≈ 4 inches thick		
2/6	016	5	500	759	28.8	3.1	1700	NA	1.04	30	Consolidated brash, uniform thickness ≈ 5 in.		15
2/6	016	6	903	941	52.9	4.1	1700	NA	0.97	30			
2/6	016	7	908	932	53.3	15.7	1900	NA	1.05	30			
2/6	016	8	197	541	11.7	NA	UNRECORDED				This ice was very thick undisturbed condition		20
2/7	017	1	1528	1050	91.6	4.5	1800	NA	NA	30	Uniform ice13 - 15 in. thick		23
2/7	017	2	1682	1057	94.5	3.1	1800	NA	NA	30			
2/7	017	3	562	815	33.6	5.5	1800	NA	1.07	30	Unconsolidated ice slush and rubble		11
2/7	017	4	503	785	29.9	5.0	1800	NA	1.07	30			11
2/7	017	5	1488	1089	85.4	5.4	1800	NA	1.07	30	Rubble 20 in. thick, 12 - 14 ft. across		20*
2/10	023	1	1062	897	60.0	6.5	TEST, RUN WITHOUT ACV BOW						10
2/10	023	2	980	920	56.7	7.8	TEST, RUN WITHOUT ACV BOW						10
2/10	023	3	963	922	56.2	5.6	TEST, RUN WITHOUT ACV BOW						10
2/10	023	4	917	926	52.4	13.6	1850	NA	--	30		Pressure gauge not working	10
2/10	023	5	471	778	28.0	4.8	1850	NA	--	30		Pressure gauge not working	10
2/10	023	6	808	913	48.0	5.6	1850	NA	--	30	Consolidated brash	Pressure tap frozen	10
2/11	024	1	920	927	55.1	3.4	1700	NA	--	30	Several speeds were run and the effects of ice build up in the cushion were observed. At slower speed ice seemed to accumulate.		11

* Estimated
** Relative Strength Factor

Table 5-4d Data Summary Sheets for Tests Conducted by the SUMAC/ACV

DATE	T.C. NO.	RUN	SUMAC				ACV				ICE CONDITIONS	COMMENTS	R.** S. F.
			TOTAL H.P.	AVG RPM	FUEL GPH	VEL. MPH	RPM	H.P.	PRES. PSI	AVG FUEL GPH			
1978 2/11	024	2	1607	1105	92.8	4.7	1700	NA	--	30	See T.C. No. 024, run 1	Pressure guage not working on ACV	13
2/11	024	3	925	937	54.0	4.9	1700	NA	--	30	See T.C. No. 024, run 1	"	13
2/11	024	4	925	937	54.3	4.3	1700	NA	--	30	See T.C. No. 024, run 1	"	13
2/11	024	5	915	941	53.8	3.8	1700	NA	--	30	See T.C. No. 024, run 1	"	13
2/11	024	6	1594	1118	94.6	4.7	1700	NA	--	30	See T.C. No. 024, run 1	"	14
2/11	024	7	1559	1109	90.6	4.6	1700	NA	--	30	See T.C. No. 024, run 1	"	14

** Relative Strength Factor

Table 5-4e Data Summary Sheet for Tests Conducted by the SUMAC/ACV

Tests with the LACV-30 were conducted with procedures similar to those used with the SUMAC/ACV; however, because of the great differences in the characteristics of the two craft, operational techniques required certain modifications. More than twenty specific data items relative to the Test Plan plus numerous other test data were collected and recorded in the Daily Operational Log (Reference 10). A summary of tests completed by the LACV-30 is presented in Table 5-5.

The SUMAC/ACV and LACV-30 were both available for testing in the Peoria area as scheduled. The SUMAC/ACV combination was in the area from 16 December 1977 to 8 March 1978. In addition, the four-day transit from St. Louis, Missouri, to Peoria, Illinois, can be considered in retrospect as test time since much valuable information was obtained. The LACV-30 reported for duty with the Coast Guard on 15 January 1978 and was in operational status until 18 March 1978 when testing was concluded. Tests were conducted to obtain operational and engineering data. Also nontesting time necessary for repairs and preventive maintenance provided an opportunity to collect additional data relative to the craft's impact on the Coast Guard design criteria for ACV icebreakers and cost data for icebreaking operations.

A breakdown of activities for each craft is presented in Table 5-6. In order to compile the table, each day's operation was classified according to the activity which predominated. For example, if five hours of one day were devoted to operations and three hours to repairs, the whole day was considered as "operations".

It can be seen that both vehicles had extensive periods of downtime for maintenance and repairs. The RIVER GUARDIAN had few mechanical problems

	TEST	TIMES PERFORMED
SPT-1*	Towboat Transit Measures	4
SPT-2	Towboat Maneuvering Measures	10
SPT-3	Icebreaking Techniques	Continuous Experimentation
SPT-4	Ice Pattern Documentation	Continuously Observed
SPT-5	Overtaking Maneuver	Numerous
SPT-6	Stopping Maneuver	Numerous, 1 Emergency
SPT-7	Cost Effectiveness	1
SPT-8	Design Criteria	Documentation as Applicable
SPT-9	Open Water Characteristics	2
SPT-10	Turning Maneuver	Numerous
SPT-11	Icebreaking Mechanism	Continuously Observed
SPT-12	Abandoned Barge	1
SPT-13	Sunken Barge	1
SPT-14	Impact Upon Coast Guard	Continuously Monitored
ADDITIONAL TESTS AND OPERATIONS		
	Extended Deployments (Up to 160 mi. radius)	4
	Multi-Day Operations (away from base at ANFAC)	21 Days
	Breaking Out of Lock Gates	1
	Ice and Channel Profile Survey	3

* SPT: Self-propelled Craft Test

Table 5-5 Summary of Tests Conducted by the LACV-30

SUMAC/ACV	Operations (Days)	Maintenance and Repair (Days)	Other (Days)
12 - 31 Dec	6	0	14
1 - 31 Jan	4	16	11
1 - 28 Feb	8	18	2
1 - 8 Mar	3	1	4
Totals	21	35	31

LACV-30	Operations (Days)	Maintenance and Repair (Days)	Other (Days)
15 - 31 Jan	1	14 *	2
1 - 28 Feb	14	7	7
1 - 18 Mar	12	6	0
Totals	27	27	9

* Including Set-Up Time

Table 5-6 Breakdown of Activities for SUMAC/ACV and LACV-30

but required frequent repairs to the skirt system because of ice damage. The LACV=30, on the other hand, was seldom down for protracted periods of time for skirt repair but needed a great deal of preventive maintenance to assure effective operation of its comparatively complicated propulsion system. Detailed records of maintenance and repairs conducted on each craft are provided in References 9 and 10.

The various tests conducted with the SUMAC/ACV and the LACV-30 not only provided data and information to support the objectives but also provided engineering and operational data which advanced the state-of-the-art in ice classification techniques, icebreaking effectiveness measurements, ice management techniques, operational noise problems and skirt failure documentation. A more complete discussion of these items is given in Section 6 of this report.

5.4 Flood Control Operations on the Kankakee River

In addition to icebreaking operations to facilitate towboat traffic, the LACV-30 was deployed to the Kankakee River to evaluate its potential in flood control operations. On the Kankakee, where commercial towboat traffic does not transit, there is no consistent channel depth and, once ice forms, the river is frozen until the end of the winter season. As the season changes from winter to spring, with warm days and freezing nights, the ice begins to break up. Variations in temperature cause the ice to begin breaking up. Ice chunks break off at expansion crack joints, which develop due to the thaw-freeze cycles, and these chunks begin to flow downstream. Channel characteristics, however, influence their path. At some points along the rivers

and streams, the channel widens but depth decreases, and ice chunks, which can be as thick as 18 to 20 inches, ground in these shallow areas and eventually pile up to a point that they dam the river. Damming can also occur at river bends and bridges. As temperatures continue to rise, the watershed increases upstream of these dams, backing up the river, overflowing its banks, and flooding the adjacent lowlands.

Because of its amphibious capability and ability to traverse obstructions, the self-propelled ACV has a good potential for success in ice jam and flood control operations. The LACV-30 was so operated in the lower Kankakee River, just above the Dresden Island Lock and Dam (110 miles north of its Peoria, Illinois base) from 1 to 18 March 1977 with good results.

5.5 <u>River Ice Environment</u>

To fully document the river ice environment, an overall ice characterization of the test area on Peoria Lake and the Illinois River was conducted. At the outset of the project, little ice formed on the river. Operations during December were for the most part conducted on open water or in water with only about 40 percent of the channel covered with thin ice. By early January, however, ice began to accumulate. During the months of January and February, the lake was mostly covered with uniform ice except in the channel area where barge traffic traveled. In the channel, there was a mixture of rafted ice, slush, brash, and imbedded plates. Figures 5-1a, b, and c summarize representative samples of ice conditions taken by aerial and surface surveys. At various times during the two months, the ice accumulated and thickened, but overall it stayed relatively stable throughout the test period.

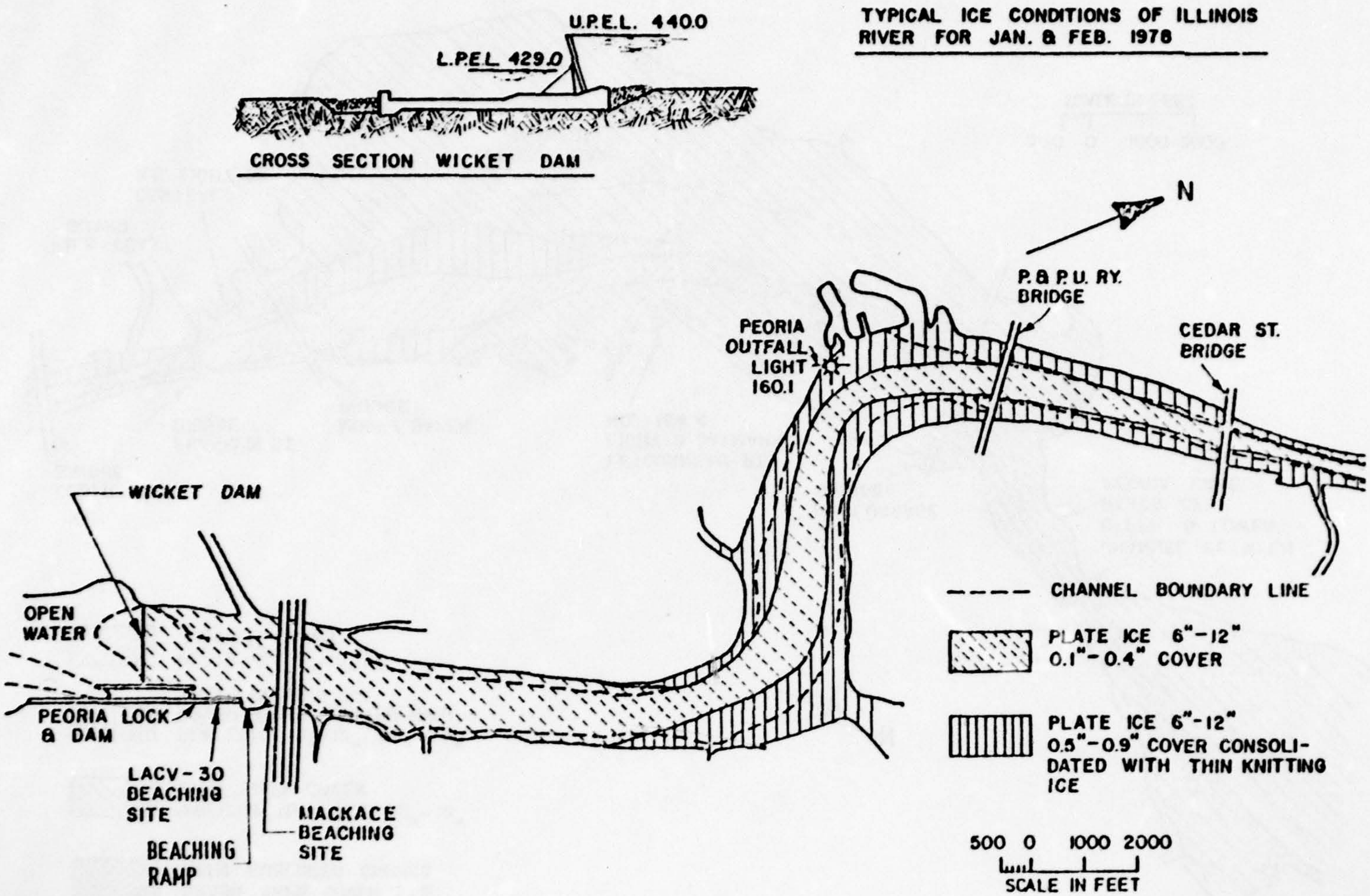


Figure 5-1a Illinois River Ice Conditions

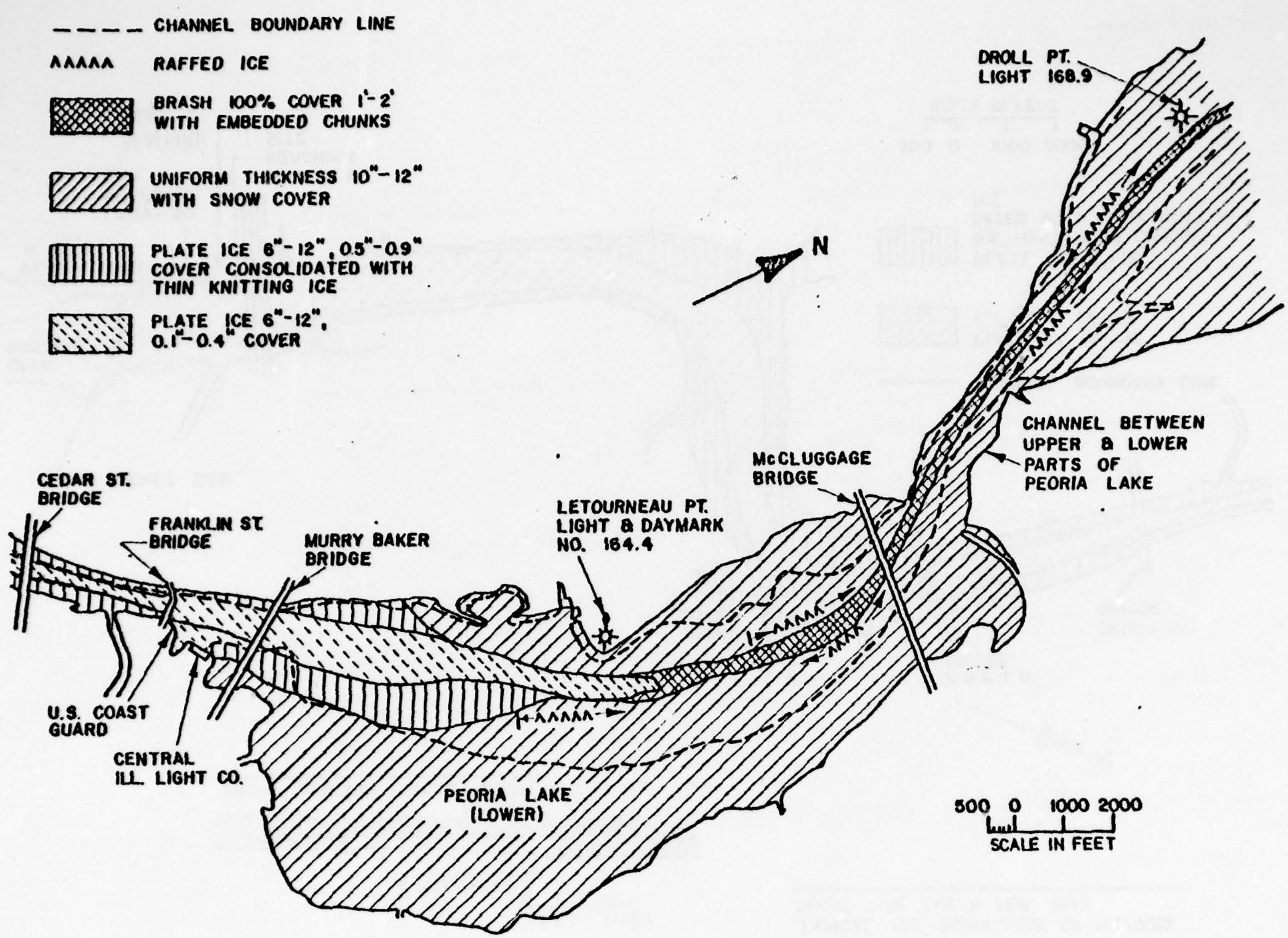


Figure 5-1b Illinois River Ice Conditions

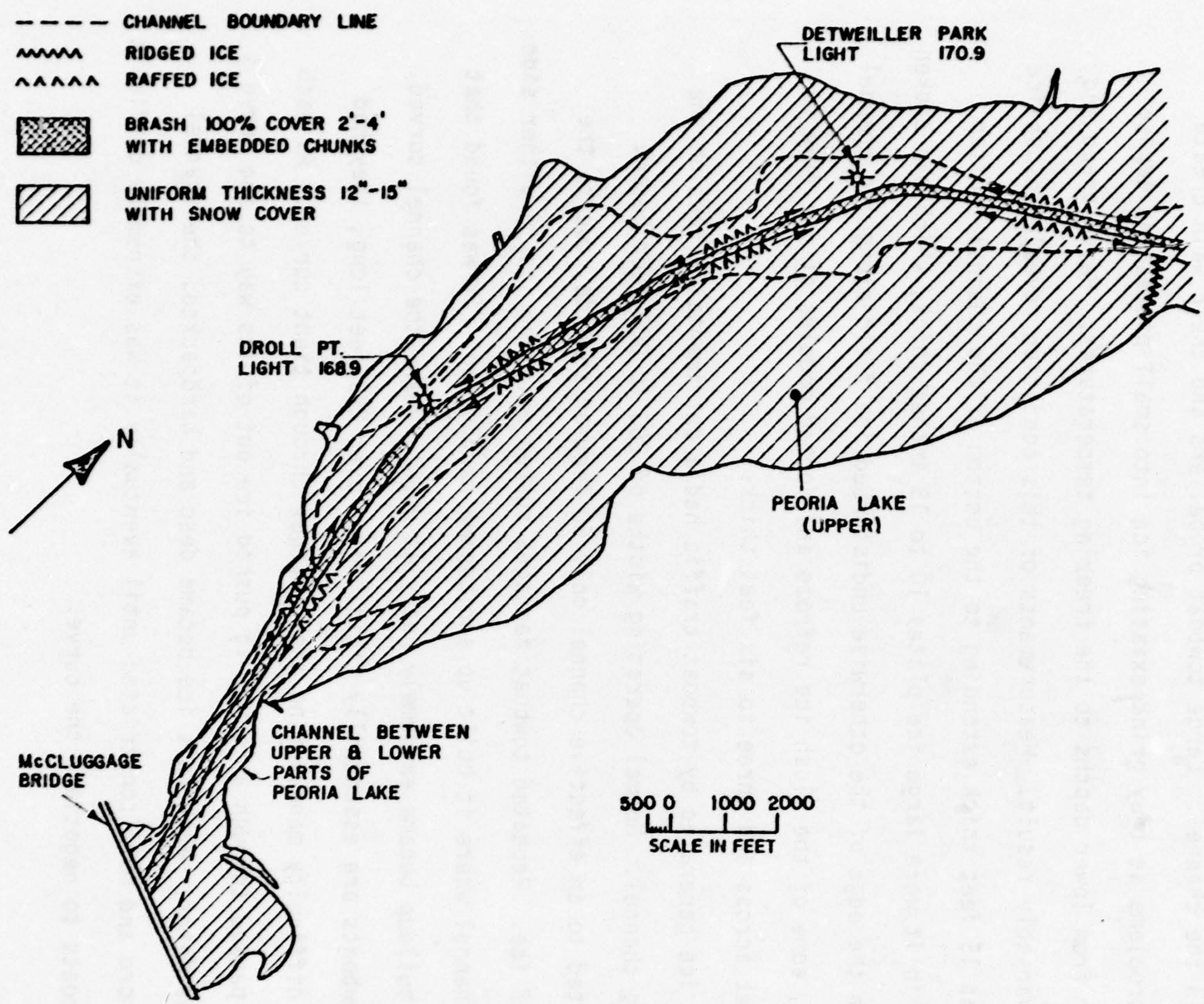


Figure 5-1c Illinois River Ice Conditions

The significant characteristics of river ice are directly related to the action of towboats passing through it, the flow of the river, the temperature regime and the bathymetry. Towboat traffic breaks up and churns the ice in the channel. Large towboat propellers and their wash create special problems as they grind existing ice into small pieces and expose new water from lower depths to the freezing temperatures. Heavy brash and slush invariably result. Measurements of this condition revealed slush ice as much as 15 feet thick extending to the bottom of the channel. Often embedded in it were large ice plates 10 to 15 inches thick, which had broken away from the edge of the otherwise undisturbed ice field along the channel. At times, some of the slush ice refroze and formed modules of ice five to eight feet across and three to six feet thick.

The ice generated by towboat traffic had a detrimental effect on the operating channel. Normal operating widths of 200 to 300 feet became constricted to an effective channel only 60 feet or so wide, due to the growth of ice. Repeated towboat passages pushed existing ice to either side of the channel where it built up and became hardpacked. It was found that the ice buildup became extremely heavy at points where the channel curved. Since towboats are essentailly rigid bodies over 200 feet long, they had extreme difficulty maneuvering their barges through tight curves. As each towboat passed through a curve, it pushed ice out of its way to the curve's outer perimeter. When this ice became deep and hardpacked, the channel became more and more constricted until eventually it was extremely difficult for towboats to negotiate the curve.

To better understand the ice environment in the Peoria Lake channel, an ice profile survey was conducted with the LACV-30. One of the measured profiles is shown in Figure 5-2. It can be seen that in the shallow portions of the river, the ice was plate ice, only 15 inches or so thick, but it had become up to 15 feet thick with slush ice in the main channel due to the action of towboat traffic. The profile was taken at an end point of a turn and indicates the growth of ice on the outer (left) edge of the turn. It can be seen that, although the channel depth allows some 350 feet of width for operations, the effective operating channel has been reduced to about 150 feet at the inside of the turn. Towboat traffic had packed the ice up so tightly that it extended above the surface as much as four feet high in certain areas.

In addition to ice profile measurements, various measurements of ice thickness, temperature, ice types and the behavior of broken ice were recorded periodically during each day of testing. Ice borings were made at locations where icebreaking tests were conducted. Table 5-7 shows some of the results of those samples. To meet the needs of the test program, comparisons of day-to-day and test-to-test data were necessary. A system of translating ice measurement values into ice classification terms was developed by characterizing the river ice environment in terms of a Relative Strength Factor (RSF) which allowed direct comparison of test data. The rationale for and use of the RSF are presented in Section 6 of this report.

The operation of the LACV-30 on the Kankakee River for flood control required environmental documentation for that location also. The ice environment was similar to the Illinois River, except that the Kankakee River does not have barge traffic. Ice profile and in situ measurements were made at

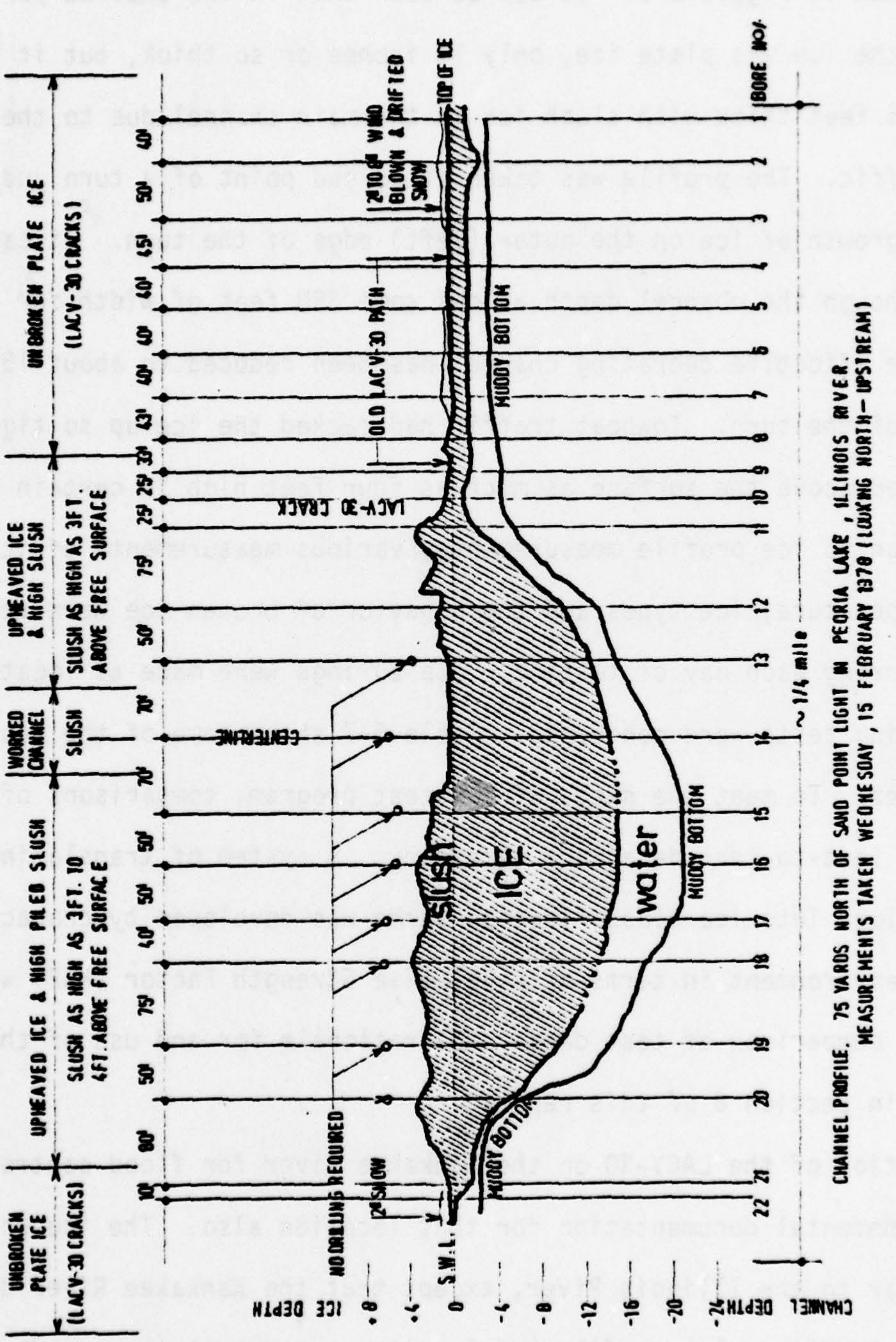


Figure 5-2 Ice and Channel Profile

DATE	LOCATION	T.C.* NO.	Plate Thickness (in)	Plate or Grain Size (ft)	Plate Spacing (in)	Knitting Thickness (in)	FIELD TYPE	ICE DESCRIPTION & COMMENTS	** RSF
1/21/78	Channel 164.4 Mi.	010	6	9	1	6	Uniform Thickness-Cold	New plate ice very little knitting and closely packed	16
1/23/78	Channel 164.4 Mi.	011	4	3	4	2	Brash-melting	Brash ice next to previously broken channel	11
1/23/78	Channel 165.3 Mi.	011	10	8	1	2	Brash-melting	Ran into heavy ridge of ice piled up to tow boats	14
1/24/78	Lake 164 Mi.	012	12	10	5	3	Uniform Thickness-Cold	Snow cover 3 inches. Ice is very thick.	16
2/3/78	Channel 159.9 Mkr.	013	6	10	12	1	Unconsolidated Brash	Ice was consolidates with .9 cover	8
2/4/78	Channel 167 Mi.	014	6	10	12	0	Unconsolidated Brash	Brash ice in place pushed up 2 to 4 feet thick	10
2/6/78	Channel 166 Mi.	016	5	10	5	2	Uniform Thickness-Cold	Plate ice refrozen into a uniform field	13
2/7/78	Lake 172 Mi.	017	16	25	1	10	Uniform Thickness-Cold	This ice was very thick previously unbroken lake ice.	20
2/7/78	Channel 167.4 Mi.	017	3	4	2	2	Brash-cold	Brash ice in channel with imbedded plate ice 8 to 10 in.	13
2/11/78	Channel 167 Mi.	024	8	4	2	6	Brash-melting	In channel ice 4 to 6 in. with 1 ft. thick at edge	14
2/11/78	Channel 167 Mi.	023	4	6	12	1	Brash-melting	No comments available	10
2/21/78	Channel 27.7 Mi.	028	12	4	6	2	Brash-cold	Refrozen brash & rubble field	13

* T.C.N. = Test Control Number and is used to correlate the handling of data collected during a particular test.

** RSF = Relative Strength Factor

Table 5-7 Summary of Illinois River Ice Conditions

various locations along the test areas. Overall, the ice averaged 21 inches in thickness, although areas of hummocked ice up to four feet thick were encountered resting on the river bottom.

An interesting observation of the ice during this icebreaking operation was its change in mechanical properties with changing temperatures. The ice became much more flexible as the temperature rose during the day and this increased flexibility had a measurable impact on its resistance to the icebreaking. The cooler, more brittle ice was easier to break than the flexible ice (Reference 9), which would often heave up and down a foot or more and remain intact as the wave generated by the LACV-30 passed over it.

6.0 RESULTS

6.1 General

The results presented in this section fall into two categories. The first presents results obtained in accordance with the objectives detailed in the Test Plan. The second covers results of additional tests and specific situations encountered. The latter category covers such subjects as ice classification, ice management, the LACV-30 icebreaking effort for flood control on the Kankakee River, and a summary of the noise level readings for both the LACV-30 and the SUMAC/ACV. Supportive data in the form of summary data sheets can be found in Section 5.3, ice classification sheets in Section 6.7, SUMAC hull survey data in Appendix B and segment failure history in Appendix C.

6.2 Facilitation of Marine Commerce

Results relative to the objective of facilitating marine commerce were obtained by conducting tests in which the SUMAC/ACV escorted towboats and their barges. These tests confirmed the utility of icebreaking operations to commercial towboats. Without exception, towboat operators polled reported that, when the SUMAC/ACV cleared the channel directly ahead of them, their vessels required less horsepower to maintain a given speed and achieved greater speeds at constant horsepower.

No tests were run to determine the ability of the SUMAC alone to facilitate river commerce by escorting towboats. In a number of instances the SUMAC alone attempted to clear the channel but failed to make substantial headway through heavy ice. It appeared realistic to conclude that the SUMAC with its displacement hull, ice deflectors and agitating propwash did contribute materially to successfully clear the channel; however, without the action of

the ACV bow, the SUMAC alone was unable to successfully break the ice in the harsh environment encountered.

During the project, team members developed an understanding of the numerous problems involved in the interaction of towboats and ice and gained insight into possible strategies for alleviating the causes of these difficulties. It was determined, for example, that the ease with which commercial traffic could transit was proportional to the width of the broken channel. On straight passages in the river, commerce was facilitated when a channel wide enough to permit two-way passage was maintained and towboats could further maneuver in an unhampered manner in order to drop off their barges. The widening of the channel at turns reduced transit time by eliminating the need for longer tows to back and fill several times to make the turn.

Because the LACV-30 had no channel clearing capability, it was not as effective as the SUMAC/ACV combination in facilitating towboat traffic through heavily packed brash ice which frequently clogged. In several operational exercises, the LACV-30 assisted barges and boats which were stuck in the ice by breaking ice in the shallow areas close to the stranded vessel, thus relieving the ice pressure and permitting the craft to extricate itself.

Although both ACV's were able to break ice, this was not a sufficient answer to facilitating towboat traffic. Ice clearance was, in fact, as great a problem as icebreaking. The current of the Illinois River was not strong enough to initiate the flow of broken ice downstream; consequently, the ice simply closed back into the channel and refroze. Icebreaking, therefore, is simply one part of a package which must be implemented

in order to facilitate river traffic. This is discussed in Section 6.10, Ice Management.

6.3 Operational Procedures

The Test Plan called for testing and documenting the operating procedures and maneuverability capabilities for both ACV's. The SUMAC, because of its draft, was restricted to operations only in the channel area of the river where the water depth was sufficient to allow its passage. The LACV-30 craft, however, was able to operate freely above ice and water so its operations were not limited by either the width or depth of the channel. Following is a synopsis of how each craft handled in open water and in ice.

Turning Maneuver

The SUMAC/ACV combination was 169 feet long* and thus required a very large turning radius. The channel width did not permit direct 180° turning but required many direction reversal maneuvers. In open water, turning was usually accomplished quickly and with relative ease. In ice-clogged channel areas, however, turning maneuvers became very difficult. The SUMAC/ACV could turn only as far as broken ice along the side of the SUMAC's stern was loose. Once the ice piled up, the stern could no longer slip sideways and a direction reversal was necessary so that the SUMAC's propwash could loosen and clear an area in the ice into which the stern could slip. With repeated reversal efforts, ice would be moved from one side of the SUMAC to the other and the turn could be effected. However, a 180° turn in ice could take anywhere from half an hour

---

* The SUMAC was 114 feet long and the RIVER GUARDIAN was 45 feet by 55 feet. During all operations after January 4, 1978, the RIVER GUARDIAN was pushed in its long direction, as shown in Figure 3-1. Thus, the total length of the SUMAC/ACV was 169 feet.

to two hours depending on ice severity.

The LACV-30's ability to turn in a very small radius meant it encountered few difficulties in maneuvering. Neither craft had problems negotiating bends in the river, although the LACV-30 could take the shortest path through a bend while the SUMAC/ACV was restricted to the channel.

Stopping Maneuver

The normal stopping routine of the SUMAC was not noticeably altered by the presence of the ACV bow. This was true even in the one emergency which occurred. The SUMAC/ACV combination was proceeding through refrozen brash ice at about four knots when the ACV's number 2 engine failed and its cushion deflated within six seconds. The SUMAC reversed engines and was able to come to a complete stop in 15 seconds. Despite ice conditions, no damage was incurred to the ACV skirt system.

Stopping maneuvers for the LACV-30 depended upon the ice environment in which it operated. On broken ice or slush, the procedure was to reverse the propeller pitch. On smooth sheet ice, pitch reversal was required well in advance of the scheduled stopping point. Additional braking could be obtained by slipping sideways and lowering hover height. If the craft was traveling at high speed, the only effective stopping maneuver entailed the execution of a pirouette. In open water, the stopping procedure is similar to that employed in broken ice; however, the craft can be stopped more quickly if necessary by dropping the cushion pressure and putting both engines on idle. As with the SUMAC/ACV, only one emergency was encountered. In this case, immediate engine shutdown at 35 mph resulted in the LACV-30 coming to a controlled stop within 225 feet.

Passing Maneuver

River operations frequently required that the ACV icebreakers pass commercial towboats and their barges. The SUMAC/ACV combination experienced little difficulty in passing, provided such operations were performed only in the channel where water depth permitted their execution. In open water or moderate ice conditions, the channel width generally varied from 200 to 300 feet and passing posed no problems. In heavier ice conditions such as those found in Peoria Lake, however, passing became a difficult and time-consuming maneuver with ice, rather than water depth, becoming the limiting factor. As explained in Section 5.5, ice would constrict the channel down to an effective width of about 60 feet. The ice on the outside of this channel became hardpacked and deep and significantly reduced the SUMAC's maneuverability. As the SUMAC/ACV pulled out of the operating channel into the hardpacked ice on the edge, the ice deflectors on its hull acted like a snow plow and began to push the ice forward with the SUMAC until it was no longer possible to push the ice mass any further. At this point, the SUMAC had to back down to clear the ice from under it before further progress could be made. Under these conditions, a passing maneuver could take more than 30 minutes.

Two other interesting observations were made during passing operations with the SUMAC/ACV. First, in heavy ice the SUMAC/ACV was forced to pass rather close to commercial towboats due to the ice-constricted channel. The powerful propellers of commercial towboats sucked in so much surrounding water that on several occasions the force drew the lighter SUMAC/ACV towards the towboat. The SUMAC/ACV then had to perform special maneuvers to avoid

collision. Another potential danger was ice damage to either the vessels or the barges as large chunks of ice were crushed between their hulls. Second, when the RIVER GUARDIAN was operating with a portion of its anti-spray skirt missing, water and ice projectiles were sprayed out 10 to 20 feet from the craft. During passing operations some spray would hit the towboat deck, creating a source of potential injury to towboat crew members on the deck.

Towboats were routinely passed by the LACV-30 in less than one minute. Generally, clearance was no problem since the LACV-30 could travel over shallow areas of the river away from the main operating channel. The only factors that might bear consideration when operating the LACV-30 close to normal river traffic would be ice projectiles from the cushion spray, possible propeller blast, and noise.

Operating Speeds

During operations in heavy brash ice it was found that the RIVER GUARDIAN operated best at speeds of approximately 3.5 to 5 mph, with cushion pressure at 1 psi and a bow-up attitude of between 1 and 1.5 degrees. When operating in heavy brash ice at lower speeds, the flexible skirt system tended to tuck under, causing the bow to dip and rendering the skirt segments susceptible to ice damage. At higher speeds this tucking action did not occur, and the bow skirt segments rode up easily over the ice. The ice modifications on the SUMAC, however, proved to be a hindrance in heavy ice. Its ice deflectors, with their snowplow action, slowed progress and made it extremely difficult to maintain optimum speed. As a result ice accumulated under the ACV's stern, which caused its bow to dip, and necessitated cessation of operations while the SUMAC backed down to clear the ice. In open water the craft could move

easily at 7 to 8 mph and was capable of 4.5 to 5.5 mph in a moderately icy channel.

The LACV-30 operated at a constant cushion pressure of 0.5 psi but its speeds varied from 10 to 35 mph. As will be explained in Section 6.8, the LACV-30's icebreaking capability at high speed (>10 mph) depended entirely on the size of wave it generated and, therefore, wave amplitude was correlated both to speed and to water depth. For open water transits on the river a speed of 35 mph was used in order to minimize the amplitude of the trailing wave. In broken ice and heavy brash, maneuvers were carried out at about 22 mph because it was found that higher operating speeds resulted in accelerated skirt wear and damage. A speed of 12 mph usually corresponded to hump speed (see Section 6.8) and was used during icebreaking operations.

For data gathering in ice conditions, project engineers found the LACV-30 invaluable. Not only did it have high speed maneuverability but it could transit over ice in shallow water regions at speeds of 35 to 50 mph. Without this capability in Peoria Lake, development of ice profile surveys (Section 5.5) would have been difficult if not impossible.

From experience gained during the test and evaluation program, icebreaking operational procedures were identified that could be generalized for either self-propelled or nonself-propelled ACV's in a river icebreaking role. Since these operational procedures are based on observations and measurements taken during a single testing period, they should be considered as guidelines and not procedures to which either type of craft should rigidly adhere.

Table 6-1 presents a summary of operational procedures for a nonself-propelled ACV. It was prepared in order to correlate the testing maneuver

MANEUVER / ICE ENVIRONMENT	THICK UNIFORM PLATE ICE	HEAVY BRASH ICE
Channel Clearance	Speed should be maintained (4 to 5 mph) to keep the momentum up and to sweep the channel as wide as possible. ACV should be bow up 1 to 1.5 degrees. Ballasted only as much to equal cushion pressure and ice thickness plus a pressure margin.	Speed should be maintained (3 to 4 mph) as long as cushion area does not become clogged If clogged, push boat must back down to clear cushion. Bow up 1. to 1.5 degrees. Increase fan flow rate to reduce possibility of tuck-under of skirt.
Enlargement of Turns in Channel	Break out channel width on outside of turns in channel to allow the towboats to swing stern around to expedite turn.	By starting on the largest radius of the turn make an icebreaking run to widen the turn, each one closer in to the inside of the turn. This is to move the heavy brash away from the outside of the turn.
Towboat Assistance	Use channel clearance description. Stopping to allow towboat to catch up if channel closes up too quickly.	Speed of icebreaking should be geared to speed of the towboat which is being assisted Because heavy brash closes in much more quickly than plate ice, the icebreaker must operate more closely to towboat.
Passing	When passing a towboat or barge speed should be kept up to maintain controllability.	To pass in a narrow channel one of the two passing vessels may have to stop to allow the other to move around and into the channel ahead or behind passed boat. There is a tendency in brash to be "sucked" into a boat or barge being passed if it is in the channel and the passing boat must go outside.
Beaching	Make a pass along beach to clear ice from beach area. Get a running start to push the ACV up on the beach as far as possible. Stand by to drop spud to reduce slide back.	Same as uniform plate ice.
Turn Around 180°	Wide radius turns should be made with caution because of potential hazard to rudders. Turn in narrow channel should be made by alternate ahead and back movements to move the ice away from the stern in order to make the turn.	A wide radius turn may be made if channel width is sufficient (300 ft.). Full rudder, inside engine full astern, outboard engine full ahead. If channel width will not permit a full turn, backing will be necessary. Care should be taken to protect turning rudder by keeping them aligned with boat. Flanking rudder may be used for turning.
Backing Down	Turning rudder must be straight with track. Use flanking rudder if a turn is desired.	Turning rudder must be straight with track. Use flanking rudder if a turn is desired.

Table 6-1 Nonself-Propelled ACV Icebreaking Procedures

with the specific environmental condition in which it was performed. In addition, only those conditions which are unique to the ACV in a river ice environment or which might prove hazardous to its operational ability are cited.

Table 6-2 describes the operational procedures for icebreaking with a self-propelled ACV and, again, is limited to those procedures which are unique to the river ice environment. It should be noted that, since a self-propelled ACV such as the LACV-30 operates in a wave generation mode, it is necessary that the pilot of the vessel be kept constantly informed of the size of the wave he is generating. At present, there is no automated way of monitoring wave size and the pilot must depend on information relayed to him by an onboard observer. Since measurements were taken from the cabin while the craft was underway and visibility from the cabin was frequently hampered by spray on the windows, collected data were often in the form of educated guesses rather than precise statistical records.

6.4 Cost Effectiveness

Originally, the Test Plan called for the evaluation of the cost effectiveness of ACV icebreakers in facilitating river commerce. The most direct means of measuring icebreaking effectiveness was to monitor river traffic through areas directly involved in the ACV icebreaking project. The nature of the project, however, was such that it was impossible to maintain an intensive commerce monitoring effort. In addition, it was realized that the direct assignment of cost values to certain aspects of river commerce would be difficult. Therefore, the requirements of this objective were modified to provide a cost analysis which would include development of a general cost model limited to ACV

MANEUVER	USE/ICE CONDITION
High Speed Low Amplitude Wave	Good for relatively thin ice, 6 to 8 inch wave propagates out bank to bank.
High Speed, Quick Slow Down to Hump Speed	Used on heavy fast ice (>18") to maximize wave for short duration.
Hump Speed	Carries maximum wave. Good for normal icebreaking rate up to 20 mph where ice pressure may be relieved by open water. Also used to reduce size of ice plates once broken out of large ice field.
Hump Speed, Side Slip	Used to carry maximum wave into thick ice and amplify wave at edge of ice field for short distance--from open water.
Edge Work	Using hump speed technique work edges of river where surface runoff water has weakened ice provided water depth is adequate.
Figure "8" or Crescent Passes	Used on edge of ice from open water where maneuvering room is available.
Criss-Cross	Used for hole enlargement when starting from a solid cover ice field repeated criss-cross is necessary to break up ice chunks as small as possible to reduce wave damping.

Table 6-2 Self-Propelled ACV Icebreaking Procedures

icebreaking and an assessment of project costs directly related to ACV icebreaking efforts.

Results of efforts addressing the modified requirements of this objective provided a preliminary cost model specifically oriented toward ACV icebreaking operations. The model consists basically of three components combined linearly to form a total cost by the formula:

Total Cost = Initial Cost + Annual Cost + Operating Cost

Each component can further be defined by dollars, dollars per year and dollars per hour, respectively.

Initial costs consist of those one-time expenditures made at the beginning of any ACV icebreaking project. These would include the cost of the vehicle, plus facilities, support and induced costs and can be broken down as shown in Table 6-3:

Vehicle Cost	Facilities Cost	Support Cost	Induced Cost
ACV Major spare parts	Land Ramp Building(s)	Major equipment Auxiliary equipment Personnel and Management	Ice Management Spillways Structural Protection

Table 6-3 Categories of Initial Costs

As this table illustrates, it is unrealistic to regard ACV icebreaking costs as consisting only of the vehicle and initial spare parts costs. Facilities costs must include those for a land area where beaching and repair tasks are conducted. The site should offer a suitable ramp to allow the ACV to enter and exit the river and buildings for equipment storage and craft shelter.

Personnel costs for vehicle operation and maintenance can be established from standard Coast Guard billet models. It will be more difficult, however, to assess the cost of project startup in terms of management. In order to have a successful operation, extensive planning must be done to assure efficient coordination of operational and maintenance efforts. An inventory system for ordering and storing spare parts will also be required.

In addition to personnel and management costs, other categories of support costs are identified in Table 6-4:

SUPPORT COST		
Major Equipment	Auxiliary Equipment	Management
Mobile crane Hot bonding equipment Generator Welder Air compressor Transportation vehicle - truck	Tools Spare parts Winches Ballast Rope and line	Start-up Coordination Inventory Storage Office equipment Bookkeeping

Table 6-4 Categories of Support Costs

Results of current icebreaking operations suggest that certain costs which are induced by such an operation bear consideration. Induced costs would result as a direct product of icebreaking efforts. For example, control of ice interference with lock and dam operations and ice damage to river structures will induce added expenses and will require some type of ice management program. A proposed ice management program is discussed in more detail in Section 6-11.

While it is possible to predict an average annual cost for ACV icebreaking efforts, the rate of operating costs depends to a great degree on craft integrity and the ice environment. In mathematical form, the operating

costs component of the model may be expressed as:

$$\text{Cost/Hour} = \frac{\text{Fuel Gallons}}{\text{Hour}} \times \frac{\text{Cost}}{\text{Gallon}} + \frac{\text{Segment Failure}}{\text{Hour}} \times \frac{\text{Cost}}{\text{Segment}} + \frac{\text{Total Operational Maintenance Costs}}{\text{Total Hours of Operation}}$$

In developing the cost model, the life of the equipment was assumed to be 10 years and operating costs were reduced to dollars per hour. Since the project was primarily research-oriented, it was not possible to assign dollar values to all the components involved in its completion. No permanent facilities were construced, the beaching ramp was merely some bulldozed dirt territory, and much of the equipment was supplied by the U.S. Army Corps of Engineers. Furthermore, both craft were available on some form of leasing arrangement. Given these limitations, the following is a proposed total cost model:

Total Cost ($/yr) = Initial Cost + Annual Cost + Operating Cost

where

Initial Cost = Vehicle Cost + Facilities Cost + Support Cost + Induced Cost

Annual Cost = Major Annual Maintenance Expense

Operating Cost = Fuel Cost + Skirt Replacement Cost + Repair Cost

Tables 6-5 and 6-6 present worksheets for a suggested model which may be applicable to future ACV icebreaking studies. As can be seen from the categories presented in the tables, itemized costs can be put in the model to provide total cost as follows:

$$\text{Total Cost (\$/yr)} = \underset{\text{Cost (\$)}}{\text{Initial}} \times \frac{1}{10\ \text{yrs}} + \underset{\text{Cost}}{\text{Annual}} + \underset{\text{Cost (\$/hr)}}{\text{Operating}} \times \frac{m\ \text{hrs}}{\text{yr}}$$

I. Initial Cost

A. Vehicle Cost

	Dollars
ACV	$560,000.00
Spares (Estimated 5% Craft Cost)	28,000.00
Total	$588,000.00

B. Facilities Cost

	Dollars
Land	
Ramp	
Building(s)	
Total	________

C. Support Cost

	Dollars
Major Equipment	
Auxiliary Equipment	
Management	
Personnel	
Total	________

D. Induced Cost

	Dollars
Ice Management	
Spillways	
Structural Projection	
Total	________

Initial Cost Total = Σ A + B + C + D $\boxed{}$

II. Annual Cost

Maintenance Costs	Dollars
Hull Maintenance	
Engine Maintenance	
Other (Itemize)	________
Total	

III. Operating Cost

Total Hours of Operation ________ Hours

A. Fuel Cost

ACV Consumption Rate ___30___ gal/hr

Cost ACV Fuel ________ $/gal

Pusher Vessel Consumption Rate ________ gal/hr

Cost Pusher Vessel Fuel ________ $/gal

	Dollars/Hr
ACV Fuel Cost	
________ gal/hr x ________ $/gal	
Pusher Vessel Fuel Cost	
________ gal/hr x ________ $/gal	________
Total	

B. Skirt Segment Cost

Cost New Segment $________

Cost Repaired Segment $________

Segment Failure Rate ___0.25___ seg/hr

% New Segments for Replacement ___30___ %

% Repaired Segments for Replacement ___70___ %

	Dollars/Hr
New Segment Replacement	
________ $/seg x ________ seg/hr x 30%	
Repaired Segment Replacement	
________ $/seg x ________ seg/hr x 70%	
Total	

C. Maintenance Cost

	Dollars/Hr
Itemize Maintenance Costs Here ÷ ________ Hours of Operation	________
Total	

Operating Cost Total = Σ A + B + C $\boxed{}$

Table 6-5 Cost Summary Worksheet for A Nonself-Propelled ACV

I. Initial Cost

A. Vehicle Cost — Dollars

ACV $2,500,000.00
Spares (Estimated 10% Craft Cost) . . . 250,000.00
Total $2,750,000.00

B. Facilities Cost — Dollars

Land . . . .
Ramp . . . .
Building(s) . . . .
Total ________

C. Support Costs — Dollars

Major Equipment . . . .
Auxiliary Equipment . . . .
Management . . . .
Personnel . . . .
Total ________

D. Induced Cost — Dollars

Ice Management . . . .
Spillways . . . .
Structural Protection . . . .
Total ________

Initial Cost Total = Σ A + B + C + D $\boxed{}$

II. Annual Cost

Maintenance Costs — Dollars

Hull Maintenance . . . .
Engine Maintenance . . . .
Other (Itemize) . . . .
Total ________

III. Operating Cost

Total Hours of Operation ______ Hours

A. Fuel Cost

ACV Consumption Rate 195 gal/hr
Cost ACV Fuel ______ $/gal

Dollars/Hr

ACV Fuel Cost
______ gal/hr x ______ $/gal . . . .

B. Skirt Segment Cost

Cost New Segment $ ______
Cost New Bag $ ______
Cost Repaired Segment $ ______
Cost Repaired Bag $ ______
Segment Failure Rate ______ seg/hr
Bag Failure Rate ______ bag/hr
% New Segment for Replacement ______ %
% Repaired Segment for Replacement ______ %
% New Bag for Replacement ______ %
% Repaired Bag for Replacement ______ %

Dollars/Hr

New Segment Replacement
______ $/seg x ______ seg/hr x ______ % =
Repaired Segment Replacement
______ $/seg x ______ seg/hr x ______ % =
New Bag Replacement
______ $/bag x ______ bag/hr x ______ % =
Repaired Bag Replacement
______ $/bag x ______ bag/hr x ______ % = ________
Total

C. Maintenance Cost — Dollars/Hr

Itemize Maintenance ÷ ______ Hours of
Costs Here Operation . . ________
Total ________

Operating Cost Total = Σ A + B + C $\boxed{}$

Table 6-6 Cost Summary Worksheet for A Self-Propelled ACV

A precise cost determination could not be made for the test and evaluation program. This was mainly due to the fact that many facilities, equipment and support items were contributed by either the Coast Guard or the U.S. Army without direct costs being assigned to the project.

6.5 Facilities/Personnel Requirements

An in-depth study of personnel skill requirements versus Coast Guard training requirements was beyond the scope of this evaluation. Coast Guard personnel from the SUMAC, the Second Coast Guard District and the R&D Center, familiar with and experienced with Coast Guard personnel skill levels in comparable jobs onboard diesel and gas turbine driven cutters, observed the ACV operations at close hand. In their judgment, both the nonself-propelled and self-propelled ACV's can be maintained and supported by Coast Guard personnel after special training specifically related to the two vastly different craft types.

Maintenance and support facilities would appear to be more significant obstacles to successful operations because of the severity of the river ice environment. The Coast Guard must therefore be prepared to provide special facilities and support equipment tailored to maintain and repair each type of ACV. Since both must be maintained and repaired in unimproved outdoor locations, it is important that adequate portable support facilities be provided.

There were, for example, numerous segment failures on the RIVER GUARDIAN during the test program. After operations in which damage was incurred to the skirt system, the craft had to be beached at the repair site near Peoria

Lock and Dam. This site was simply a bulldozed dirt ramp with a dirt area at the top where both ACV's could be parked for repair. The beaching operation for the RIVER GUARDIAN was conducted by using a Caterpillar tractor and a winch truck to pull the craft up the beach incline and to maneuver it on land so that maintenance personnel could have access to the area under the craft which required repair. This work was often performed in freezing weather on poor terrain with only makeshift tents and portable heaters to provide some element of comfort. As a result of these beaching and repair operations, it became evident that more emphasis should be placed on considering the supportability and maintainability of the ACV in the field.

There are considerable differences in support requirements for nonself-propelled and self-propelled ACV's. Clearly, since the nonself-propelled craft works in tandem with a sizeable pusher vessel, some repair equipment can be carried aboard the latter. Emphasis should be placed, therefore, on providing maintenance support for the ACV while it is actually away from port.

Table 6-7 is a partial list of suggested facilities and equipment necessary for the supportability of a nonself-propelled ACV. It is divided into items that would be located at ACV beach facilities and portable items that could be carried on board the pusher vessel.

The LACV-30 posed two problems which were not present in the nonself-propelled ACV. First, it can run at high speeds and thus range a considerable distance away from any land-based maintenance and repair facilities. Secondly, since it is self-contained it does not have the physical capacity to hold large amounts of equipment or to carry extra crew specifically assigned maintenance and repair tasks. Experience gained in the early part of the

FIXED BASE ITEMS
Repair and servicing ramp area, hard surface with shallow graded ramp from water's edge Capstan winch or winch truck* for beaching Tugger winches for stability control during ACV movement on land Storage and repair building(s) Crane truck* or equivalent to handle lifting of segment frames, etc. Electric welder and related barge repair items Sewing machinery and hot bonding equipment for repair of rubber skirts
PORTABLE ITEMS
Heaters with fans and tent covering for worker protection from weather during repairs Diesel engine maintenance tools Electric/pneumatic hand tools, e.g., impact wrench, riveting gun, drill Portable segment frame handler Assorted tools for pulling and repairing segments Deck ice removal gear, ice chippers, rubber hammers, etc. Heavy duty industrial stapler and segment repair kit

* Crane and winch trucks can also travel to remote beaching sites when repairs away from base are required.

Table 6-7 Equipment for Nonself-Propelled ACV

test program provided a basis for the choice of equipment which was carried aboard the LACV-30 as it traveled from Peoria to the Kankakee River for flood control icebreaking operations. Table 6-8 presents a list of both fixed base and portable items required to maintain and support a self-propelled ACV.

As has been stated, operation of either type of ACV icebreaker is well within the capability of existing Coast Guard personnel and technological levels. Coast Guard crews, with their basic knowledge of vessel operations, maintenance, and repair, would be adequately qualified to handle the barge-type ACV. The only requirement would be to gain some elementary background on air cushion dynamics and the ACV skirt system characteristics. Most training could be completed on the job and should involve both operators and maintenance personnel, since it is important that each component of the crew learns to recognize the first indications of any malfunction in the craft. With this capability in hand, personnel could probably perform more repair tasks while the vessel was operating and avoid time-consuming and complicated beaching operations.

The LACV-30, on the other hand, is a complex piece of machinery which requires a trained crew. This craft requires a trained operating crew and a maintenance crew capable of working on turbine engines and flight systems such as propellers and aircraft navigational controls, in addition to less technical tasks such as skirt repair and replacement. The Coast Guard would have to initiate special training programs to give personnel direct experience in operating and maintaining an ACV of the LACV-30 type.

FIXED BASE ITEMS
Building and Yards Building and yard facilities should be designed to allow the craft to fly from the river to the service area. The ramp must be graded to assist in maintaining and guiding the craft in a prescribed track. The low speed maneuverability of these vehicles is marginal and they tend to seek the path of least resistance. Any grade in the transiting surface will cause the craft to drift. **Machinery** It may be necessary to lift at least 2/3 of the weight of the craft and to place blocks under the landing pads so access may be gained to the bottom. A crane of the required capacity should be available. It will be necessary to move the craft in areas where good surfaces are not available. This requires a tow truck to pull the craft around. In addition, another vehicle is needed to stabilize the craft from the stern. They should be of such weight and bollard capacity to handle the craft in the expected terrain.
PORTABLE ITEMS
Skirt repair equipment, i.e., riveting tools, welder, etc. Air compressor Brush clearing equipment (chain saws, axe, etc.) Engine repair tools Portable heaters and covering to protect workers during repair periods Fuel supply

Table 6-8 Self-Propelled ACV Facilities and Equipment

6.6 Design Criteria

This section discusses design problems which became apparent during the testing of both the self-propelled and nonself-propelled ACV's.

Skirt System Material

One of the major design considerations to come out of the icebreaking test and evaulation program was the effect of the harsh ice environment on the skirt system material. The skirt material employed on the RIVER GUARDIAN weighed 60 oz/sq yd. It was made of rubber reinforced with a single weave nylon fabric. During the project this material proved to be inadequate for the severity of the ice encountered. The LACV-30 employed materials of several different weights. These materials consisted of neoprene reinforced with a two-ply weave of nylon fabric and did not have the high failure rate of the naterial used on the RIVER GUARDIAN.

Tensile strength and tearing tests were conducted at Virginia Polytechnic Institute (VPI) on sample skirt material from both craft and the two-ply material proved to be of greater strength. It should be pointed out, however, that there is no basis for any direct operational comparison between the materials used on either ACV. The RIVER GUARDIAN had a straight finger-type skirt design and operated with much higher cushion pressure than the LACV-30, which had a bag and finger-type skirt formation and operated at much higher speeds.

To extend the life of the skirt segments on the RIVER GUARDIAN, liners were installed inside the bow segments. The bow area had experienced the

highest rate of segment failure as evidenced in the damage diagram shown in Appendix C. The liners, which were made of polyvinylchloride (PVC) bonded over a nylon fabric, contributed significantly to the improved operational life of the RIVER GUARDIAN's skirt system. In addition, a bumper system of cut tires was added over the bow skirt section to reduce the impact of ice on the skirt. It was not readily apparent to what extent this bumper system improved skirt segment life but some type of bumper system might be considered in future nonself-propelled ACV designs.

Spray Suppression System

During icebreaking operations ice accumulated on the decks of both the RIVER GUARDIAN and the LACV-30. The amount of ice that accumulated was directly related to the amount of spray generated by the craft.

The RIVER GUARDIAN had a spray suppression skirt configuration which contributed significantly to minimizing the amount of spray generated by the air cushion. Such a system would have been desirable on the LACV-30 and should be a design consideration in future ACV designs.

Ice accumulation proved to be a problem which often interfered with operations. Ice buildup on the forward deck of the RIVER GUARDIAN contributed on occasion to its bow down attitude. Also, ice accumulated on the fan intake structure of the RIVER GUARDIAN and, at one point, effectively reduced the hover height by constricting the air flow.

Ice accumulation due to spray directly affected the operations of the LACV-30 by impairing visibility. Because the LACV-30 used the wave generation

mode of icebreaking, it was important to monitor closely the speed of the craft and relate this to the amplitude of the wave it was generating. On some occasions, personnel on the LACV-30 could not clearly see the characteristics of the wave due to marginal visibility which resulted from spray freezing to the windows of the craft. In addition, only the forward windows of the craft were equipped with windshield wipers.

Other Observations

Many other items relating to ACV icebreaker design criteria were developed during the project. Table 6-9 presents suggested design criteria items for a nonself-propelled ACV and Table 6-10 presents design criteria for a self-propelled ACV.

- o Dimensions of craft should be compatible with barge size for optimum channel clearance, e.g., 45 ft. by 55 ft. or greater
- o Minimize above deck clutter of equipment and structure to reduce problems of deck ice accumulation and to reduce sail area
- o Spray suppression skirt should be included in the design
- o Cleats, chocks, bits and pad-eyes should be designed for beaching operations and for facing up to towboat
- o Push pads and restraining rigging must be designed to allow for movement of the ACV during hover height changes, but should restrain ACV so as not to allow a bow down attitude thus preventing plow-in
- o Skirt material should be 90 oz/sq yd, or heavier, advisably of a double weave construction with high tear resistance
- o Skirt segment design should include rip-stop fabrication. The back of each segment should be enclosed to minimize ice scooping and to maintain pressure in the segment greater than the cushion.
- o Means for varying cushion pressure (ballasting) should be provided. Ideally cushion pressure should be adjustable over a range of 0.8 psi to 1.5 psi.

Table 6-9 Nonself-Propelled Craft Design Criteria Items

- o External wipers should be provided to help keep all windows clear of spray and ice
- o A spray suppression system should be installed to minimize spray
- o Deck clutter should be kept to a minimum in order to reduce the area where ice can accumulate
- o A deck winch system should be included to assist in pulling the craft free during possible ice groundings
- o Crew comfort during long missions should be considered and areas for food storage, etc., provided
- o A variable ballast system should be installed, which would permit cushion pressure and center of gravity location to vary. The suggested cushion pressure range is 0.3 to 1.0 psi.

Table 6-10 Self-Propelled Craft Design Criteria Items

Items from Table 6-9 which might require further explanation include:

1. The spray skirt design on the RIVER GUARDIAN provided no rip stops and, consequently, when a puncture or tear in the material began, it quickly grew and extended from the top to the bottom of the segment. Future designs should incorporate some rip stop seams to localize rips and prevent their spread, thus enabling craft to maintain hover height.

2. Each segment of the RIVER GUARDIAN was enclosed in back to prevent it from scooping up broken ice as the craft moved over the ice field (See Figure C-1, Appendix C). Unfortunately, however, these backs were usually ripped off the segments by the harsh ice. Further study is needed to fully understand the effects of this design feature on skirt life and cushion pressure.

3. Minor effects on the steering of the SUMAC were often noted when cross channel winds hit the ACV bow. It might be desirable, therefore, to reduce the sail area on a barge-type ACV by placing the fuel tanks and engines below

deck, if possible. It should also be noted that by reducing the number of items on deck (deck clutter), the number of points where ice can accumulate is effectively reduced.

An item from Table 6-10 which might require further explanation follows: The fact that ice often protruded four to five feet above the water surface can be seen in the ice channel profile (Figure 5-2, Section 5.5). During one operation the LACV-30 was approaching such an ice mass and reduced speed, hoping to avoid it. Unfortunately, the craft did not stop in time and came to rest on the ice mound. There it became high centered and was effectively grounded. Efforts to free the craft using on-board deck winches were ineffective, and the help of a commercial towboat in the area had to be enlisted. Future ACV designs should include sufficient deck equipment to free the craft in similar situations.

A more complete treatment of design criteria is presented in Reference 9. The information is divided into five areas: hull, power, life arrangements, auxiliaries and supportability. It is not intended to be a complete set of specifications for the design and construction of an ACV icebreaker, but a presentation of design criteria items that are considered as necessary or desirable in ACV icebreaking operations.

6.7 A Method for Characterizing River/Lake Ice (Relative Resistance Factor)

During the test and evaluation program there was a need to compare results from various locations and time frames of test runs. In addition, ice environments needed to be compared to determine the effectiveness of icebreaking under varying craft configurations. As a result of this, a standardization of river ice environment was achieved by developing a

Relative Strength Factor (RSF) method of characterizing the ice. This methodology employed measurement of specified ice parameters such as thickness, plate size, plate spacing, and knitting thickness. It also considered the classification of the total ice field, e.g., melting brash, uniform cold ice and similar conditions. The resulting procedure produced a number which described the unique river ice condition during a particular test situation. This permitted comparison of test data and icebreaking effectiveness over a span of time and locations. Equal RSF values indicate ice conditions which present similar resistance to breaking and/or resistance to channel clearance.

Table 6-11, Ice Parameter Values and Unit Strength Factors, is the basic form used in developing the relative strength values for each test. This form and procedure were used by various test engineers during the test program. Results were compared between recorders and a weighted averaging resulted in the final RSF value. Tables 6-12a, b, c, and d contain the ice classification forms used to record the ice parameters, field type, comments, and calculated resultant RSF.

6.8 Icebreaking Mechanisms

In general, ACV's break ice in two different modes depending on their speed and cushion pressure and on the type and thickness of the ice encountered. The two modes are wave generation and water depression. Since the nonself-propelled ACV operates mainly at low speeds with a high cushion pressure, it breaks ice in a water depression mode. The self-propelled ACV usually operates at high speeds with low cushion pressure, and thus breaks ice in a wave generation mode.

INSTRUCTIONS: By measurement determine ice parameters, thickness of plate, size of plate, plate spacing, and thickness of knitting holding the ice mass together. Select the unit strength factor (U.F.) for the existing ice. Next by observation determine ice field type and select U.F. for that type. Add up all U.F.'s. The resulting value represents the relative strength of that ice field and is a measure of resistance of the ice to breaking and displacement.

ICE PARAMETERS		U.F.*		U.F.		U.F.		U.F.		U.F.		U.F.	U.F.
Thickness (Avg.) of Plate	Inches (1-4)	1	Inches (5-8)	2	Inches (9-12)	3	Inches (13-15)	4	Inches (16-19)	5	Inches (20-25)	6	Over Use 7
Plate or Grain Size	Feet (1-4)	1	Feet (5-8)	2	Feet (9-12)	3	Feet (13-15)	4	Feet (16-19)	5	Feet (20-25)	6	Over Use 7
Plate Spacing	Inches (1-4)	5	Inches (5-8)	4	Inches (9-12)	3	Inches (13-15)	2	Inches (16-19)	1	Inches (20-up)	0	
Knitting Thickness	Inches (1-2)	1	Inches (3-5)	2	Inches (6-8)	3	Inches (9-11)	4	Inches (12-up)	5	--	-	

* U.F. = Unit Strength Factor

Ice Field Type	U.F.
Uniform Thickness Unbroken - Cold	3
Refrozen Brash/Plate - Cold	4
Uniform Thickness Unbroken - Melting	2
Refrozen Brash/Plate - Melting	3
Unconsolidated Brash	1

Table 6-11 Ice Parameter Values and Unit Strength Factors

Relative Strength Factor (RSF)

DATE	T.C. NO	RUN	PARAMETERS: THICKNESS OF PLATE (IN.)	PARAMETERS: PLATE OR GRAIN SIZE (FT)	PARAMETERS: PLATE SPACING (IN.)	PARAMETERS: KNITTING THICKNESS (IN.)	FIELD TYPE: UNIFORM COLD ICE	FIELD TYPE: BRASH COLD ICE	FIELD TYPE: UNIFORM MELTING	FIELD TYPE: BRASH MELTING	FIELD TYPE: UNCONSOLIDATED BRASH	RELATIVE STRENGTH	DESCRIPTION AND COMMENTS
1977 12/29	003	1	10 / 3	4 / 1	12 / 3	0 / 0					1	11 *	Brash field unconsolidated - reconstructed data*
12/30	004	1	3 / 2	5 / 2	12 / 3	0 / 0					1	9 *	Brash field unconsolidated - reconstructed data*
1978 1/11	005	1	8 / 2	- / -	- / -	- / -				3		12 *	Brash consolidated ice up to 14 inch average 6 - 8 inches, estimated ice data*
1/11	006	1	4 / 1	8 / 2	1 / 5	4 / 2	3					13 *	Uniform unbroken ice - reconstructed data*
1/14	008	3 & 5	12 / 3	8 / 2	0 / 5	12 / 4			2			16 *	Uniform unbroken ice in Peoria Lake - reconstructed data*
1/17	009	3 - 8	8 / 2	4 / 1	9 / 3	10 / 3				3		12 *	Brash consolidated, some imbedded plates - reconstructed data*
1/21	010	1	6 / 2	9 / 3	1 / 5	6 / 3	3					16	New ice very closed packed field
1/21	010	2	12 / 2	14 / 4	7 / 4	12 / 5	3					18	Ice measured 29 cm thick snow cover 2 inches
1978 1/23	011	1	4 / 1	3 / 1	4 / 5	2 / 1	3					11	Brash ice next to already broken channel at beginning of test
1/28	011	1a	10 / 3	8 / 2	1 / 5	1 / 1	3					14	We came into a ridge of ice piled up by the barges
1/27	011	2	5 / 2	4 / 2	2 / 5	2 / 1	3					13	This ridge was estimated to be 3 to 4 feet thick.
1/23	011	3	10 / 3	6 / 2	1 / 5	2 / 1	3					14	Very thick slush and plate ice.
1/24	012	1 & 2	13 / 4	10 / 3	5 / 4	3 / 2	3					16	Show cover 3 inches, ice very thick.
1/24	012	3	8 / 3	4 / 1	12 / 2	2 / 1	3					10	Raffed up, 1 foot thick.

*Relative strength factors reconstructed from test records not determined directly using RSF in characterization technique.

Table 6-12a Relative Strength Factors

Relative Strength Factor (RSF)

DATE	T.C. NO.	RUN	PARAMETERS: THICKNESS OF PLATE (IN.)	PARAMETERS: PLATE OR GRAIN SIZE (FT.)	PARAMETERS: PLATE SPACING (IN.)	PARAMETERS: KNITTING THICKNESS (IN.)	FIELD TYPE: UNIFORM COLD ICE	FIELD TYPE: BRASH COLD ICE	FIELD TYPE: UNIFORM MELTING	FIELD TYPE: BRASH MELTING	FIELD TYPE: UNCONSOLI-DATED BRASH	RELATIVE STRENGTH	DESCRIPTION AND COMMENTS
1978 1/24	013	4	10 / 3	6 / 2	1 / 5	2 / 1	3					14	Raffed ice, 2 feet thick, heavy.
1/24	012	5	10 / 3	8 / 3	1 / 5	2 / 1	3					15	*Raffed ice up to 10 feet thick in some places.*
2/3	013	1	6 / 2	10 / 3	20 / 3	1 / 1					1	10	Ice was unconsolidated brash ice, provided little resistance, .9 cover.
2/3	013	2	4 / 1	3 / 1	0	0 / 1					1	4	Ice brash about 3 feet thick along side of SUMAC 2 ft. in front of ACV, resistance relatively high.
2/3	013	3	6 / 2	10 / 3	12 / 3	0 / 1					1	10	Brash ice 3 to 4 ft. ahead, 5 ft. along side, plate imbedded in brash.
2/4	014	1	6 / 2	8 / 2	24 / 0	0 / 1					1	6	Brash unconsolidated 2 ft. thick imbedded chunks 10 in. thick 4 to 8 ft. across
2/4	014	2	6 / 2	8 / 2	24 / 0	0 / 1					1	6	Brash unconsolidated 3 ft. thick imbedded chunks 8 to 10 in. thick, 8 ft. across
2/4	014	3	12 / 3	10 / 3	12 / 3	2 / 1					1	11	Brash ice beginning to consolidate, photo 2 to 3 feet thick.
2/4	014	4	10 / 2	10 / 3	12 / 3	2 / 1				3		12	Brash ice with balls of ice 5 feet thick
2/4	014	5	10 / 3	10 / 3	12 / 3	2 / 1				3		13	Brash ice with ice balls 10 ft. thick, slush
2/6	016	1	5 / 2	10 / 3	5 / 4	2 / 1	3					13	Plates of ice broken into 3 ft chunks
2/6	016	2	6 / 2	6 / 3	5 / 4	2 / 1		4				14	Consolidated brash and plates
2/6	016	3	6 / 2	4 / 1	2 / 4	4 / 2		4				13	Consolidated brash of uniform thickness ≈ 4 inches
2/6	016	5	10 / 3	6 / 2	2 / 4	4 / 2		4				15	Consolidated brash with imbedded plates 15" thick

Table 6-12b Relative Strength Factors

Relative Strength Factor (RSF)

DATE	T.C. NO.	RUN	PARAMETERS: THICKNESS OF PLATE (IN.)	PARAMETERS: PLATE OR GRAIN SIZE (FT)	PARAMETERS: PLATE SPACING (IN.)	PARAMETERS: KNITTING THICKNESS (IN)	FIELD TYPE: UNIFORM COLD ICE	FIELD TYPE: BRASH COLD ICE	FIELD TYPE: UNIFORM MELTING	FIELD TYPE: BRASH MELTING	FIELD TYPE: UNCONSOLIDATED BRASH	RELATIVE STRENGTH	DESCRIPTION AND COMMENTS
1978 2/6	016	6	2 / 6	1 / 4	5 / 2	3 / 6		4				15	
2/6	016	8	4 / 14	4 / 15	4 / 6	2 / 9			2			20	This ice was very thick and undisturbed condition
2/7	017	1	5 / 16	6 / 25	5 / 1	4 / 10	3					23	Uniform thickness with chunks measuring 20 inches average 18 inches
2/7	017	3	1 / 3	1 / 4	5 / 2	1 / 2	3					11	This reading was in the channel and taken on the fly
2/7	017	4	1 / 3	1 / 2	4 / 2	2 / 3	3					11	Unconsolidated ice slush in channel rubble ice
2/7	017	5	6 / 20	3 / 12	0 / 24	1 / 0					1	11*	Rubble 20 inches thick 12 to 14 feet, 90% cover *this should be RSF=20
2/10	023	1	1 / 4	3 / 8	3 / 12	1 / 1			2			10	Lightly consolidated uniform thickness plates
2/10	023	2	1 / 4	2 / 4	4 / 6	1 / 1			2			10	Lightly consolidated uniform thickness plates
2/11	024	1	1 / 4	1 / 4	5 / 2	1 / 1				3		11	Thin consolidated brash
2/11	024	2	2 / 6	1 / 4	5 / 2	2 / 4				3		13	This measurement covers runs 2, 3, and 4
2/11	024	5	2 / 8	1 / 4	5 / 2	2 / 4				3		13	Consolidated brash fairly uniform thickness in channel
2/11	024	7	2 / 8	1 / 4	5 / 2	3 / 2				3		14	Rafted in areas immediately outside. Runs 16 and 17 same
2/11	025	1	2 / 8	2 / 8	5 / 4	3 / 6			2			14	N.A.
2/21	028	1	2 / 8	1 / 3	4 / 6	1 / 1						NA	Rubble chunks & slush balls with plates 4 - 6 in.

Table 6-12c Realtive Strength Factors

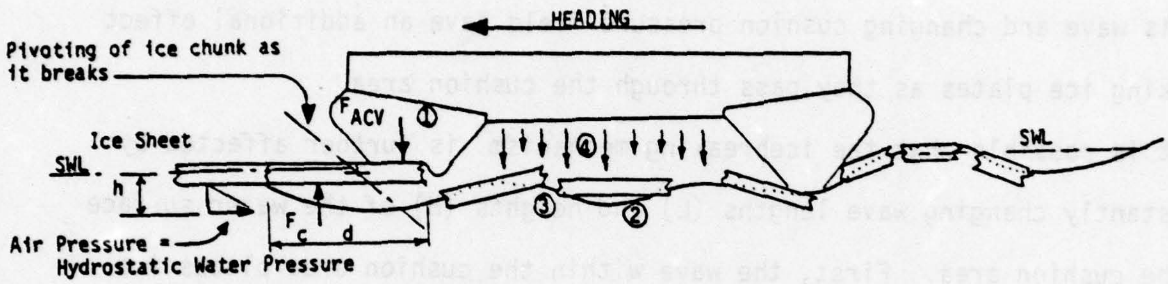
Relative Strength Factor (RSF)

DATE	T.C. NO.	RUN	PARAMETERS: THICKNESS OF PLATE (IN.)	PARAMETERS: PLATE OR GRAIN SIZE (FT)	PARAMETERS: PLATE SPACING (IN.)	PARAMETERS: KNITTING THICKNESS (IN)	FIELD TYPE: UNIFORM COLD ICE	FIELD TYPE: BRASH COLD ICE	FIELD TYPE: UNIFORM MELTING	FIELD TYPE: BRASH MELTING	FIELD TYPE: UNCONSOLI-DATED BRASH	RELATIVE STRENGTH	DESCRIPTION AND COMMENTS
1978 2/21	028	2	3 / 12	1 / 4	4 / 6	1 / 2		4				13	Refrozen brash and rubble field (location Beardstown 97.9 mile)
2/21	028	3	3 / 12	3 / 12	3 / 12	2 / 3		4				15	Refrozen channel

Table 6-12d Relative Strength Factors

While the above mechanisms are accepted as standard, there exist other phenomena in each icebreaking mode that have not been carefully studied, such as those associated with the air pressure field moving across an ice sheet. If one analyzes the plenum characteristics and air dynamics of an ACV cushion relative to the response of the water surface under the pressure field, three factors which influence icebreaking capabilities can be identified. The first is the depression of the water surface under the leading edge of the ice, which leaves the ice block extended as a cantilever beam. The second factor is that a wave is always generated by the advancing pressure field. The third is that cushion pressure fluctuates at a high frequency. These physical phenomena were identified during over 400 hours of testing the SUMAC/ACV and the LACV-30 and were found to be common to both vehicles.

Careful analysis of actual icebreaking mechanisms in the water depressing mode revealed that it is not enough simply to hypothesize that ice, acting as a cantilever, breaks downward due to the burden of its own weight (Reference 11). Actual observations indicated that as the bow skirt section of the ACV moved onto the leading edge of the ice field, the air from the cushion was forced ahead of the craft, displacing the water under the ice by a distance d. The gauge pressure between the ice and the water below it is equal to a hydrostatic head of water h (where $P_g = \rho g h$). The strength of the ice may be exceeded by this applied pressure so that, when it is broken, it actually bends upward rather than falling downward due to its own weight. In other words, the force of upward air pressure combined with the downward pressure exerted by the craft form a bending moment, causing the ice to pivot and break off. Figure 6-1 presents a rudimentary force



1. As the ACV moves forward, the bow segments press down on the face of the leading edge of the ice sheet. The water is forced out from under the ice, causing the ice to cantilever. The ice thus fails from the moment created by the ACV bow pressing down and the air pressure pushing up.

2. The predominant icebreaking mode of the self-propelled ACV is its ability to generate a large stern wave by using low cushion pressure at or near hump speed. As the wave passes through the cushion, it places hogging and sagging loading on the ice chunks which then fail due to cyclic fatigue.

3. As ice chunks collide in the cushion area, they are further broken into much smaller pieces.

4. It is possible that the high frequency variations in the cushion pressure are near the natural frequency of the ice. This may cause the ice to vibrate, accentuating the thermal cracks and causing additional failures.

Figure 6-1 Diagram of Icebreaking Mechanism

diagram which illustrates this phenomenon.

In addition to the above icebreaking mechanism, the water depression mode has several other interesting aspects. As the ACV moves forward, the advancing pressure field creates a wave. Its length and height are influenced both by the speed and the cushion pressure of the ACV. It is proposed that this wave and changing cushion pressure field have an additional effect or breaking ice plates as they pass through the cushion area.

It is possible that the icebreaking mechanism is further affected by the constantly changing wave lengths (L) and heights (H) of the water surface under the cushion area. First, the wave within the cushion area places ice plates passing under the craft through cyclic and variable loading patterns, causing them to flex in hogging and sagging actions. Secondly, the waves generate a motion which continually impacts the ice, causing it to break into smaller pieces.

Another phenomenon which might contribute to ice failure is high frequency vibration induced by cushion dynamics. These vibrations may possibly be near the natural frequency of the ice, causing it to vibrate at or near resonance. No data are presently available to verify this hypothesis, but Figure 6-1 presents a suggested conceptual diagram and a summary of a proposed icebreaking mechanism model.

For the wave generation icebreaking mode, the wave generated by the craft is the primary icebreaking mechanism and its character depends upon the craft's speed and cushion pressure, the prevailing ice conditions, and the depth of the water. At low speeds, the bow wave preceding the craft is small and cushion pressure is inadequate to depress the water level and cause the ice to cantilever. As speed increases, however, the craft

actually overtakes the bow wave and eventually rides up over it. "Hump speed" is the term used to describe this condition, which is accompanied by a stern wave of large amplitude, and it is considered the optimum condition for effective icebreaking. It is important to note that if the speed of the craft exceeds hump speed, icebreaking effectiveness is decreased since the vessel actually outruns the wave and causes its amplitude to lessen.

Since wave amplitude is the predominant icebreaking force in the wave generation mode, the wave length (L) and height (H) directly dictate the amount of ice broken. Cyclic loadings from hogging and sagging actions take place in the wave behind the craft, and impact between chunks of ice also adds to the reduction of plate size.

An important parameter identified with both modes of icebreaking is the nature of the ice environment, including the type of ice and the characteristics of the channel. While icebreaking in lakes generally involves uniform ice and unrestricted channel width and depth, the river ice environment presented challenges of a different nature. For example, SUMAC/ACV icebreaking operations on the Illinois River were confined to the channel area where the ice consisted of refrozen brash of porous consistency. In contrast to uniform plate ice which can be cantilevered by air cushion pressure, the porous brash ice absorbed and dissipated air through its cavities. Water forced out of these cavities was evident as spray points visible 50 to 100 ft. away from the ACV. Similar to the cantilever beam effect described above, this air pressure in the cavities helped break ice apart as the ACV rode up over the leading edge of the ice. Wave action

and agitation under the cushion area further helped reduce the size of the ice chunks. The SUMAC's propellers were also responsible for grinding ice while its "V" shaped ice deflectors and powerful propwash helped displace the broken chunks to the sides of the channel. The ice would soon close in behind the SUMAC/ACV combination, however, when the propwash subsided due to the lack of currents strong enough to wash the broken ice downstream.

The barge-type ACV responds in different ways when it encounters ice. This response is dependent on the amount of ballast, trim and cushion pressure which the vessel carries and also upon whether the ice field is of uniform thickness, is consolidated or unconsolidated brash, and to what extent it covers the channel. The nonself-propelled vehicle tends either to ride up on the ice prior to breaking it or to pitch down by the bow and plow in. To prevent unnecessary plow-ins, this type of ACV should be ballasted bow up 1 to 1.5 degrees with cushion pressure maintained near 1 psi. Should all these conditions exist, the ACV generally behaves in the following manner:

Upon contact with a large unbroken ice field of uniform thickness, the bow of the nonself-propelled ACV pitches upward and rides over the ice. Air progresses forward of the skirt system and depresses the water surface under the ice. Portions of the ice field fail and large broken plates tilt upwards, venting the air pressure beneath them. The ACV then pitches back down to equilibrium as the broken ice chunks of approximately 10 to 15 feet across pass into the cushion.

Expectations were that the self-propelled LACV-30 would be able to use its wave generation capability to break ice from riverbank to riverbank. This, however, did not always happen because of characteristics of the

channel. First, the water depth changed greatly across the 200-300 feet wide channel, from 18 to 30 feet in the main channel to from 0.5 to three feet at the shore. Since wave propagation is dependent on water depth, amplitudes generated in the deep water of the main channel were damped out in the shallow waters along the banks. Second, waves generated in open water or brash ice were damped out by solid plate ice at the edge of the channel. The harsh nature of the brash ice in the operating channel and the lack of current to flush broken ice meant that waves generated by the LACV-30 were not effective in clearing the channel. It broke plate ice on the edge of the channel, but this was of little use to commercial traffic because the water depth there was too shallow for passage. In addition, when the LACV-30 broke ice bordering the channel in Peoria Lake, the chunks sometimes moved into the main channel and created more problems.

Thus, it can be seen that the river ice environment offers several new factors to be considered in the field of ACV icebreaking. The entire field of ACV technology is relatively young and some ideas on icebreaking mechanisms are presented for the first time in this report. Observations made over the period of the study have explained some of the physical responses of the vehicles and the ice as it was broken. Further study of the icebreaking phenomenon under more controlled conditions is now necessary to provide knowledge which could be of fundamental importance in designing more effective ACV icebreaking vehicles.

6.9 Icebreaking Effectiveness

A rational criterion of measuring icebreaking effectiveness is difficult to establish. It would be a sweeping simplification to define

effectiveness of icebreaking as the area of ice broken per hour. First, it is necessary to identify where the ice was broken, since operations in the channel area would obviously have more effect on river commerce than those in shallow waters. Secondly, it is important to consider the quality of the broken ice. Small pieces of broken ice are harmless while large pieces could present a danger for downstream traffic and could even clog locks some distance away. Another factor, first recognized by the Canadians, is the amount of resistance that the ice exerts on the icebreaking craft. Resistance decreases as the size of the broken ice chunks decreases.

The resistance is reflected to a degree by the amount of energy consumed by the icebreaking vessels. In this project, the SUMAC broke ice with and without the ACV on its bow. Data were gathered on the craft in both operating modes and are presented in Table 6-13. The test runs were purposely planned in order to assess performance in RSF ice environments which were essentially the same; hence, the ice resistance factor could be considered as constant.

To illustrate comparative icebreaking performance with and without the ACV bow, consider data items 7 and 8 in Table 6-13. Item 7 records the action of the SUMAC alone operating at an engine rpm reading of 633 from open water into an ice field with an RSF of 15. It failed to make any headway and, in fact, came to a full stop within 1.5 boat lengths. Data item 8 records a run in which the SUMAC with the ACV bow attached encountered an RSF 15 ice field and, with an rpm setting of 759, was able to pass through it at 3.1 mph. Item 9 reflects a continuation of item 7 and shows that the SUMAC alone in the ice field required 1153 rpm with 1955 hp in order to pass through the ice field at approximately 3 mph. Although it succeeded in making headway, it is important to note that its fuel consumption was

DATA ITEM	RPM	H.P.	FUEL GPH	SPEED MPH	WITHOUT ACV	WITH ACV	R.S.F.	T.C. NO.	FOOT NOTE
1	1066	1671	97.0	6.2	X		12	009	*
2	1105	1607	92.8	4.7		X	13	024	
3	897	1062	60.0	6.5	X		10	023	
4	851	585	39.2	3.6		X	13	016	
5	1154	1746	111.7	4.2	X		12	009	*
6	1118	1594	94.6	4.7		X	14	024	
7	633	316	18.8	N.A.	X		15	012	**
8	759	500	28.8	3.1		X	15	016	
9	1153	1955	115.5	2.9	X		13	012	***
10	921	857	50.3	3.1		X	12	014	

* Estimated RSF

** The SUMAC took a running start and hit ice at an estimated 4 mph. The boat stopped dead within 1 1/2 boat lengths.

*** This reading was taken after the reading in item 7 and was the power required to make headway in the ice.

Table 6-13 Comparison of Icebreaking With and Without ACV

115.5 gph. This must be compared with data item 10 in which the SUMAC/ACV combination passed through a similar ice field at 921 rpm and 857 hp with fuel consumption of only 50.3 gph. Overall, the SUMAC consumed 44 percent less fuel when it operated with the ACV bow. It should be noted that this was for the SUMAC alone. It was not possible to directly record the fuel consumption of the RIVER GUARDIAN itself since it varied greatly depending on the ACV engine rpms. Calculations of the RIVER GUARDIAN's fuel consumption, however, revealed an average of 30 gph.

Table 6-14 represents a summary of icebreaking rates under various ice conditions with the rate represented in acres per hour (R_A) where 1 acre equals 43,560 square feet. These data can be analyzed by comparing the rate of icebreaking (R_A) with the ice environment (RSF) and the rate (R_A) vs the power consumed (hp). All data items reflect icebreaking runs with the SUMAC/ACV combination, except items 5, 16 and 18. It can be seen that the SUMAC/ACV was capable of breaking ice at a rate of nine acres per hour in ice with an RSF of 13 and 28 acres per hour in ice with an RSF of 10.

Because LACV-30 testing emphasized operational evaluation and comparative icebreaking techniques, it is much more difficult to quantify its actual rate of icebreaking. For example, values of 17 acres per hour in an RSF ice field of 23 were recorded during the Kankakee River operation, but these figures should be used with caution. The craft's effectiveness was hampered throughout the entire operation by a malfunctioning propeller pitch control which considerably reduced its maneuvering capability.

The use of ice resistance as a determining value of effectiveness was first employed by the Canadians in their ACV icebreaking studies (Reference 11), and a figure in their report, showing a resistance factor

ITEM NO.	AVG. RPM ENGINE	TOTAL H.P.	SPEED MPH	SUMAC FUEL CONSUMP.	RATE* BROKEN	% CHANNEL COVERED WITH ICE	WIDTH OF CHANNEL BROKEN	RSF	T.C. NO.	NOTES
1	1044	1069	3.4	71.7	22.7	100	**	7	003	Channel closed in immediately after passing.
2	996	1015	5.0	60.5	91	N.R.	150	9	004	Estimated RSF
3	724	147	2.5	9.0	18.2	---	60	N.R.	005	Ice consolidated brash 6 to 8 inches thick. The channel cleared was 100%, however, it closed back in within 100 yards of the passing. This test was run on only the keel engine with the other two idling.
4	964	1223	3.2	69.4	33	80	85	16	008	Run 3 - Estimated RSF ice 30 inches thick, some ice cracking was visible 50 yards either side of broken channel.
5	1154	1246	4.2	111.7	20	---	40	12	009	This data point represents the SUMAC breaking ice alone. Ice closed within one ship length behind boat.
6	594	262	1.8	15.5	15	95	70	16	010	Run 1 - This ice field was unbroken uniform ice 10+ inches thick.
7	908	839	3.8	34.5	23	95	50	18	010	Run 3 - This ice field was unbroken uniform ice 13+ inches thick. This test was terminated because of a bow down due to a blown segment.
8	989	1100	3.4	64.0	20	95	50	14	011	Run 2 - Brash ice, some areas raffed up by tows 3 feet high, *consolidated.*
9	1153	1955	3.0	115.5	18	95	50	11	012	Run 3 - Brash consolidated field 8 inches thick, some raffing, SUMAC prop wash cleared channel about 100 feet wide, however, it would close in again ≈ 150 feet behind.
10	579	240	3.4	13.8	18	60	45	10	013	Run 2 - Brash unconsolidated with occasional ice plates 6 to 8 inches thick.
11	921	857	3.1	50.3	11	90	30	12	014	Run 4 - Heavy brash unconsolidated and consolidated areas. Slow speed was required to prevent plow in of ACV bow.
12	579	255	2.4	14.8	9	90	30	13	016	Run 1 - Plate ice 90% cover with new knitting ice 3 inches thick.
13	759	500	2.6	28.8	9	95	30	15	016	Run 5 - Heavy consolidated brash.
14	1050	1528	4.5	91.6	24	90	45	23	017	Run 1 - Solid uniform ice 15 to 18 inches thick. Entered ice from running start.
15	1057	1682	3.1	94.5	17	90	45	23	017	*Run 2 - Same ice conditions as T.C. 17, run 1, settled down to* steady state conditions.
16	897	1062	6.5	60.0	24	50	30	10	023	Run 1 - Tight consolidated uniform thickness ice. Run made with SUMAC only, no ACV.
17	913	808	5.6	48.0	27	20	40	10	023	Run 6 - Run conducted in same area as T.C. 23, run 1, but with ACV attached.
18	922	963	5.6	56.2	20	50	30	10	023	Run 3 - Run conducted without ACV, light ice conditions.
19	926	917	5.7	52.4	28	20	40	10	023	Run 4 - Run conducted with ACV, same ice and area as T.C. 23, run 3.
20	927	920	3.4	55.1	12	90	30	11	024	Run 1 - Consolidated brash having a tendency to pile up under cushion.
21	1109	1559	5.6	90.6	20	90	30	14	024	Run 7 - Heavy brash packing up under cushion, most likely due to SUMAC's bow, necessitated frequent stops to clear cushion.

* Rate broken in acres per hour, 1 acre = 43,560 sq. ft.
$\frac{BV}{8.25} = \frac{\text{Acres}}{\text{hr}}$ where B is the breadth of the channel broken
V is speed in mph

** Assumed to be width of ACV which is either 45 ft. or 55 ft. depending on which side was faced up to the SUMAC.

NR Non-recorded, i.e., did not get recorded during test run.

The T.C. Nos. do not run consecutively because some tests, such as stopping and maneuvering, were not intended to obtain data on rate of icebreaking.

RSF - Relative Strength Factor

TC - Test Control Number

Table 6-14 Summary of Icebreaking Rate Data

vs the Froude number has been accepted as a standard method for demonstrating icebreaking effectiveness. This figure, reproduced as Figure 6-2, shows a plot of a non-dimensionalized resistance in ice factor, $R/\rho gBh^2$ vs Froude number (based on ice thickness). An upper line on the figure shows the resistance of the push boat ALEXANDER HENRY without the ACV and a lower line is the resistance of the ship with the ACV. It should be noted, however, that lowered resistance alone is misleading as an indicator of system effectiveness. The resistance of the pusher vessel is quite naturally lower since the ice had already been broken by the ACV before it encountered the hull of the pusher vessel. Resistance encountered in pushing the ACV over the ice field is not comparable to that which the pusher vessel alone would encounter in breaking the ice pack. Also, the price for the lowered resistance is paid in terms of the capital cost of the ACV with its installed power together with its amortization, fuel, and maintenance costs. A more complete indicator of effectiveness should reflect the degree to which the total system accomplishes its total mission, which is to provide a navigable channel.

An outgrowth of this test and evaluation program has been the development of a theory for measuring icebreaking effectiveness in terms of the effect of broken ice on a non-icebreaking vessel following in the channel. It is now proposed that consideration be given to the development of a comprehensive model which will serve this purpose. During the course of the project, an initial attempt was made to lay the methodological groundwork for such a model and an <u>Effectiveness Index</u> was developed. It is intended to serve as a tool of quantification to provide a number which will indicate how well an ACV configuration is accomplishing its mission of making rivers

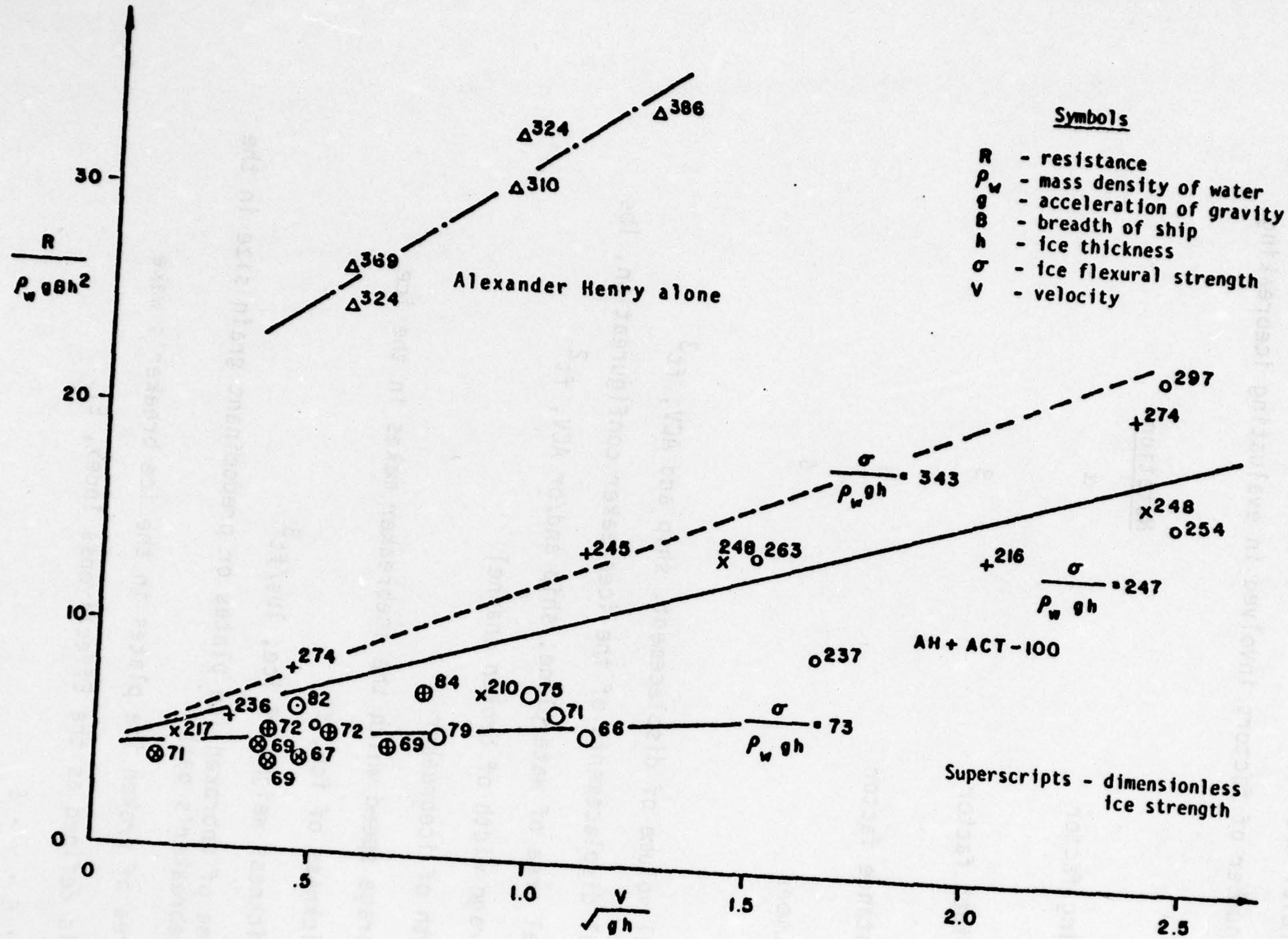


Figure 6-2 Dimensionless Resistance versus Dimensionless Velocity

passable for commercial traffic.

There are a number of factors involved in evaluating icebreaking effectiveness:

Factor		Notation
$\frac{A_i}{A_f}$	Ice crushing factor	α
$\frac{B_c}{B}$	Channel width factor	β
$\frac{tW_{ice}}{\Delta/Awp}$	Ice resistance factor	γ
$\frac{V}{\sqrt{g\nabla^{1/3}}}$	Froude number	δ

Where ∇ = total volume of displacement, ship and ACV, ft^3

Δ = total displacements of the icebreaker configureation, lbs

A_{wp} = total area of waterplane, ship and/or ACV, ft^2

B_c = average width of broken channel

B = width of icebreaker

V = average speed which the icebreaker makes in the ice

t = thickness of ice, ft

W_{ice} = thickness weight of ice, lbs/ft^3

A_i = area of unbroken ice plates or predominant grain size in the icebreaker's path

A_f = area of broken ice plates in the ice breaker's wake

The product is defined as the Effectivenss Index, E_I.

$$E_I = \alpha \cdot \beta \cdot \gamma \cdot \delta$$

By taking the product of these factors we are, in effect, placing equal importance on each. An alternative scheme which would permit weighting of cost factor would involve a weighted sum.

$$E_I = W_\alpha \cdot \alpha + W_\beta \cdot \beta + W_\gamma \cdot \gamma + W_\delta \cdot \delta$$

where W_α, W_β, W_γ, W_δ are weighting factors assigned in order of the relative importance of each factor.

The Effectiveness Index, E_I, considers only the effectiveness with which an ACV configuration accomplishes its mission. Power was not introduced because power is not a cost item. It is reflected in the capital cost of the system, fuel costs and maintenance costs. The variable which we will define to characterize the power is:

$$P_I = \frac{\Delta \cdot V}{P}$$

where P = total power, including cushion power, of the system. Thus a higher value of P_I indicates a more favorable use of power.

A plot of P_I vs E_I for the various cases tested can be made to illustrate graphically the interrelationships of these variables and show the relative effectiveness of each icebreaker configuration in performing its mission. Such a plot was considered to be beyond the scope of this project.

6.10 Ice Management

It became apparent early in the test and evaluation program that effective icebreaking operations should involve the establishment of a system of ice management which breaks the ice in the channel but does not create new problems elsewhere by the presence of broken ice. It was observed, for example, that currents on the Illinois River and in Peoria Lake were not strong enough to flush broken ice downstream and that ice

disposal was as great a problem as icebreaking. Furthermore, floating chunks of broken ice interfere with lock and dam functions and are a potential source of damage to these and other river structures, such as bridge piers and boat docks.

In recognizing and understanding the complexity of ice problems, several factors were identified which require attention if a comprehensive ice management system is to be developed. Specifically, the system should provide:

- Strategies for implementing induced flow through problem areas of the river
- Spillways to route ice chunks safely around lock and dam facilities
- Proper protection for hydraulic structures against ice induced damage
- Coordination of icebreaking efforts to ensure a passable river channel

A suitable ice management program would be advantageous in several ways. Close monitoring of conditions from the onset of the ice season would identify areas of ice buildup. Early and coordinated icebreaking efforts could control gorging and other complications. These efforts should help assure a navigable channel for towboats. A beneficial side effect would be reduction of spring flooding potential.

Associated closely with ice management is the control of river traffic in ice-clogged regions. During the project, it was observed that towboats can transit problem areas if they cooperate by using teamwork and a one-way traffic scheme. In such problem areas as Peoria Lake, one-way traffic regulation would prevent two towboats heading in opposite directions

from meeting in the middle of the ice-constricted channel. When a confrontation of this nature occurs, the passing operation forces the hardpacked ice at the edge of the channel back into the channel, with the result that navigation in that area is once again impeded. In the one-way system, towboat operators work in teams to push barges alternatively upstream and downstream across problem areas. Teamwork operations can further assure that barges which have to be abandoned are pushed far enough out of the main channel so as not to become obstacles to traffic. The one-way traffic and teamwork system was witnessed during the project, but not all towboat operators honored it. Its advantages should be obvious to all towboat operators, and the system could be managed by the industry itself without the necessity of government involvement.

6.11 Icebreaking for Flood Control

The operation of the LACV-30 in icebreaking for flood control contributed significantly to the understanding of ACV icebreaking technology. The operation resulted in a very successful effort and, according to the U.S. Army Corps of Engineers, Chicago District, was fundamental in averting possible serious flooding in the lower Kankakee River area.

This operation demonstrated some unique aspects of the icebreaking which had not been demonstrated previously. These are:

- Operating the ACV for extended periods away from the main base support facilities.
- Operating in restricted areas with little room for maneuvering.

- Operations which required transit over land to go around bridge obstructions
- Operations out of normal towboat channel
- Operations in breaking up gorged ice conditions
- Operations requiring icebreaking starting from a hole cut in the ice for that purpose
- Operations in proximity to populated residential areas
- Direct measurement of the relationship between wave patterns generated and icebreaking results
- Coordination of icebreaking with river flow control using the Dresden Island Dam settings.

Icebreaking for flood control was conducted on the Kankakee River from 1 March 1978 to 18 March 1978. The ice broken during this operation was approximately 20 inches thick and it was broken at rates up to 17 acres per hour.

6.12 Sound Levels

Whenever possible, sound levels were monitored for both craft using a sound level meter manufactured by the Bruel and Kjaer Instruments Co., Inc. (Type 213H). Readings were recorded on clear days with low wind conditions. The following section presents sound level information for both ACV's.

Sound levels on the RIVER GUARDIAN itself during operations ranged from 80 decibels (db) to 124 db depending on location. The 80 db reading was recorded inside the control cabin with the door closed while the readings of 124 db were recorded when the sound level meter was placed flush against the fan intake openings. However, five feet away from the openings of each fan intake the sound level dropped to 110 db and average deck level sound readings varied between 98 db and 108 db.

Readings on the SUMAC also varied widely. While pushing the RIVER GUARDIAN, readings of 62 to 64 db were recorded on the bridge with the doors closed, 96 to 104 db on the main deck, 76 to 80 db in the crew's quarters*, and 103 db in the engine room.*

Figure 6-3 provides a diagram of sound level readings at various distances away from the SUMAC/ACV as it proceeded with its operations.

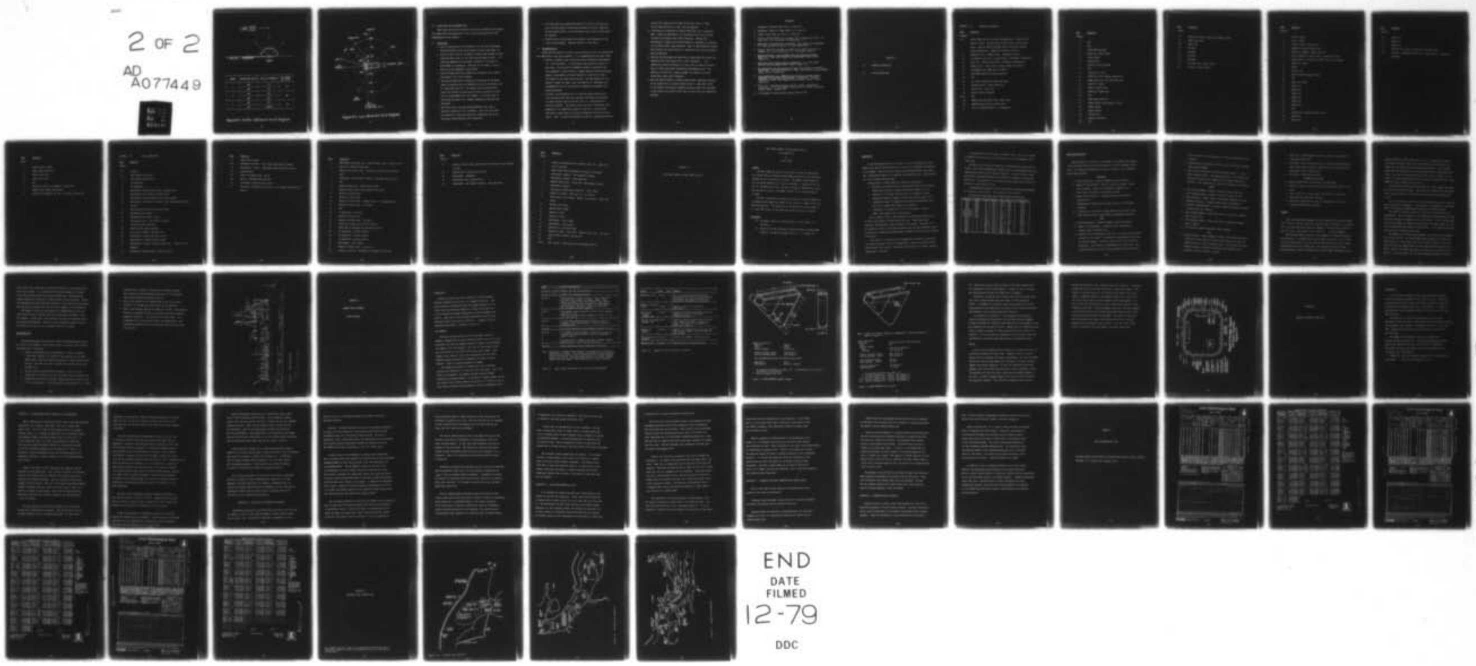
It was not possible to gather sound level readings around the deck of the LACV-30 while it was operating because it was physically dangerous. Levels inside the control cabin varied from 74 db when idling to 92 db during maneuvers. Figure 6-4 provides a diagram of sound level readings at various distances away from the LACV-30 as it proceeded with its operations on the Kankakee River. In addition to these readings, reports were registered that the craft could be heard up to eight miles away. It is interesting to note that in comparison, a 707 aircraft registered 111 db on take-off and a DC-9 aircraft registers 102 db (Reference 12).

Surprisingly enough, despite the high sound levels of the craft, there were no complaints from the residents during icebreaking operations for flood control on the Kankakee River. The 116 db readings were taken within 25 feet of the craft on the Will County Bridge where there were many spectators. Those residents were more interested in the operation's goal of flood prevention. It is unclear whether public reaction would be the same elsewhere.

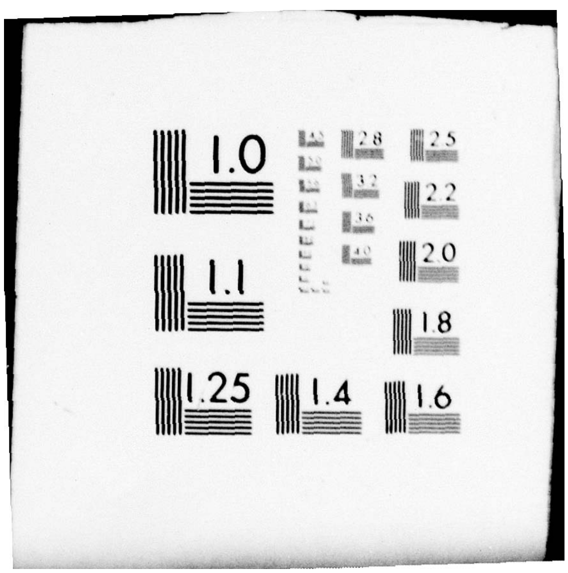
* Readings in the crew's quarters and the engine room were made with and without the ACV bow attached to the SUMAC. The crew's quarters were noisy because they were in the SUMAC's stern section right over the propellers. Ice could be heard hitting the propellers and engine whine also added to the sound level.

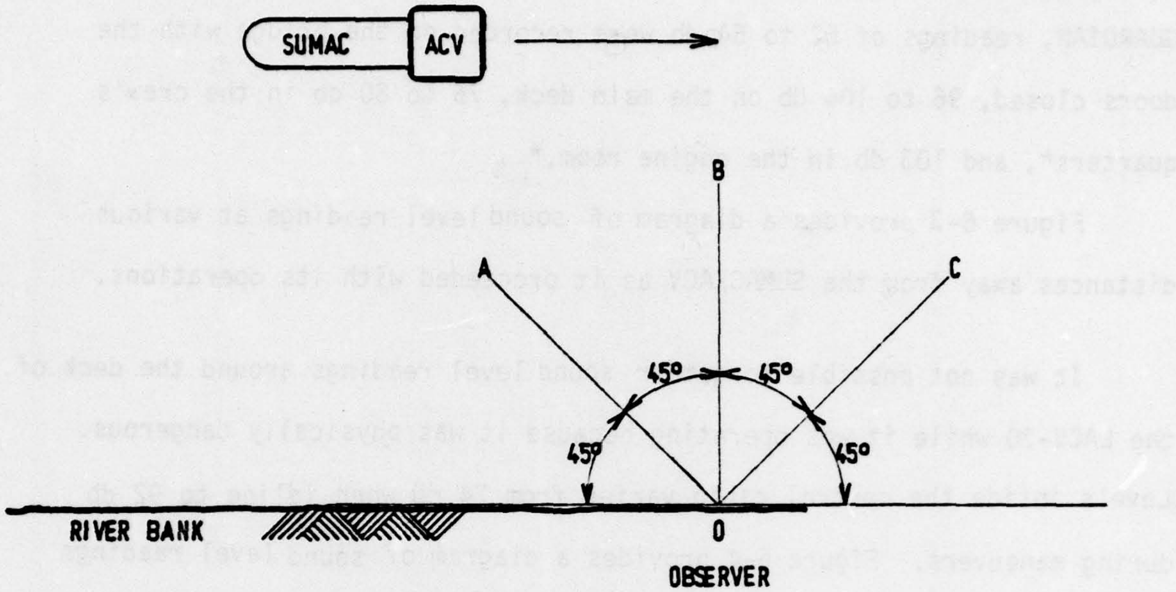
AD-A077 449 COAST GUARD RESEARCH AND DEVELOPMENT NTER GROTON CT F/G 13/10
AIR CUSHION VEHICLE (ACV) ICEBREAKER ST AND EVALUATION PROGRA--ETC(U)
AUG 78 J BUCK , B DENNIS , J ANTHONY E NEAL
UNCLASSIFIED CGR/DC-13/78 USCG -22-79 NL

2 OF 2
AD
A077449



END
DATE
FILMED
12-79
DDC


1.0
2.8
2.5
3.2
2.2
3.6
4.0
2.0
1.1
1.8
1.25
1.4
1.6



READING	DISTANCE FROM ACV (FEET)	NOISE LEVEL READING (db)	ACV LOCATION REL. TO BANK
A	200	74.5	45°
	400	57.0	
B	150	77.0	90°
	500	65.5	
C	200	71.5	135°
	600	58 TO 60	

Figure 6-3. Sumac / ACV sound level diagram

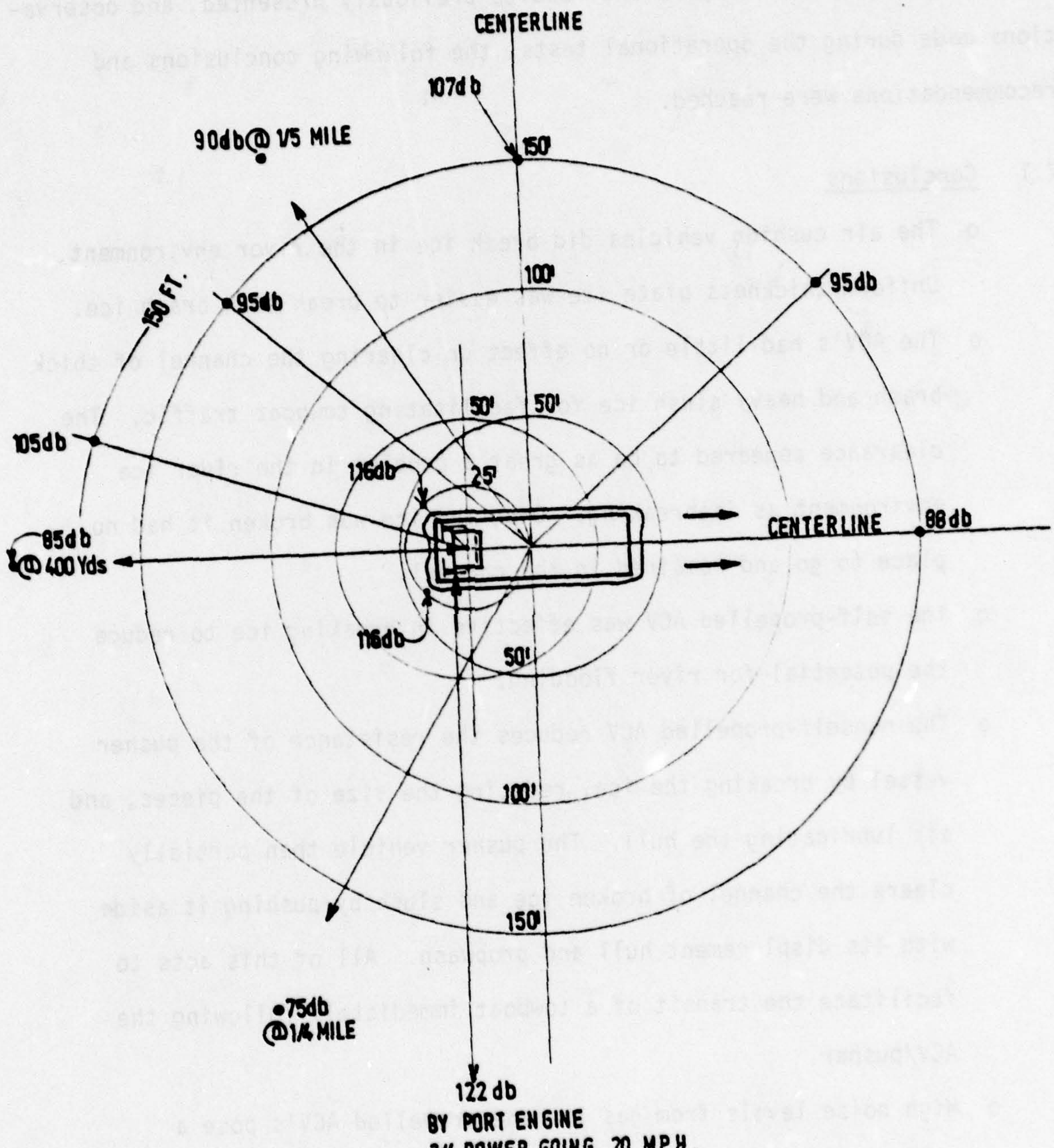


Figure 6-4. Lacv-30 sound level diagram

7.0 CONCLUSIONS AND RECOMMENDATIONS

Based upon the analysis and results previously presented, and observations made during the operational tests, the following conclusions and recommendations were reached.

7.1 Conclusions

- The air cushion vehicles did break ice in the river environment. Uniform thickness plate ice was easier to break than brash ice.
- The ACV's had little or no effect on clearing the channel of thick brash and heavy slush ice for facilitating towboat traffic. The clearance appeared to be as great a problem in the river ice environment as icebreaking. Once the ice was broken it had no place to go and remained in the channel.
- The self-propelled ACV was effective in breaking ice to reduce the potential for river flooding.
- The nonself-propelled ACV reduces the resistance of the pusher vessel by breaking the ice, reducing the size of the pieces, and air lubricating the hull. The pusher vehicle then partially clears the channel of broken ice and slush by pushing it aside with its displacement hull and propwash. All of this acts to facilitate the transit of a towboat immediately following the ACV/pusher.
- High noise levels from gas turbine propelled ACV's pose a potential problem for local residents. Such high noise levels are inherent to turbo-prop propulsion systems but may be controlled by future designs of ACV propellers.

- The Coast Guard can operate and maintain air cushion vehicles with only a minimal amount of additional personnel training. Operation of self-propelled ACV's is the area where most of the training would be required.
- The 60 oz/sq yd single weave skirt material was inadequate for the river ice environment. Adequate material is available.

7.2 Recommendations

Based upon the analysis, results, and conclusions, as well as observations and experiences of the test personnel, it is recommended that the Coast Guard:

- Perform a complete study of the Coast Guard icebreaking requirements for inland waterways. The following items should be included in the study: ice and traffic management schemes, conventional and ACV icebreakers, winter severity, clogged channel clearing techniques, commerce requirements and season extension on particular rivers. The outputs of the study should include: the requirements for icebreakers (number and type), costs and benefits of icebreakers and recommendation for the facilitation of commerce and potential for season extensions.
- Evaluate a self-propelled ACV in a long-term multi-mission role. A self-propelled ACV should be acquired, configured and outfitted for other missions such as SAR and A to N in a long-term multi-mission evaluation. The vehicle should be used in roles which take advantage of its amphibious capability (such as in shallow water SAR) and its speed (such as servicing navigation aids which are far apart). Then, it should be deployed for specific icebreaking missions

such as early opening of the Upper Mississippi River or flood control applications on a river like the Kankakee.

- o Investigate new techniques to better define the river ice environment. Study the applicability of classifying the river ice using the Relative Strength Factor (RSF) technique. Improve the methodology of comparing the effectiveness of icebreakers by developing an effectiveness index procedure. Both of these technical studies would advance the understanding of icebreaking and river ice environment technologies.
- o Consider the development and operation of barge-type ACV's which are compatible with Coast Guard WYTL or WYTM icebreakers. This combination should be operated in rivers, bays or lakes on the East Coast or Great Lakes where icebreaking requirements exist. The addition of the ACV will greatly augment the capability of the conventional Coast Guard icebreaker.
- o Keep the towing industry informed through formal Technology Transfer of the capabilities of nonself-propelled ACV's. When their reliability becomes sufficiently accepted, operators should be encouraged to push them at the head of their tows to solve their own icebreaking problems.

REFERENCES

1. Commandant (G-CPA/84) Memo 7100/1 of 3 May 1977.

2. Commandant (G-000-2/74) Memo 3900-15 of 3 June 1977.

3. G-DOE-3 letter 3936 Ser 30175 of 14 June 1977.

4. Contract (DOT-CG-74401-A) of 31 August 1977 to Mackley Ace (USA), Inc, Suite 1205, 1101 17th Street, NW, Washington, D. C.

5. Memorandum of Understanding, 29 December 1977, between the Commandant, U.S. Coast Guard (G-D) and the U.S. Army (MARAD COM 3).

6. Contract (DOT-CG-81-78-1856), Engineering and Support Services, 29 November 1977, to Chi Associates, Inc., Arlington, Virginia.

7. Executive Summary: ACV Icebreaker Test and Evaluation Program. Report, U.S. Coast Guard Research and Development Center, Groton, Connecticut.

8. Test Plan for Air Cushion Vehicle Icebreaking. U.S. Coast Guard Research and Development Center, Groton, Connecticut.

9. ACV Icebreaker Test and Evaluation Program (Supplementary Information). Unpublished. Available from the U.S. Coast Guard Research and Development Center, Groton, Connecticut.

10. Daily Operational Log: SUMAC/ACV and LACV-30 Air Cushion Vehicle Icebreaker Test and Evaluation Program. Unpublished. Available from the U.S. Coast Guard Research and Development Center, Groton, Connecticut.

11. Ball, M.A., "Continuing Advances with Air Cushion Icebreaking." Proceedings of the 10th Canadian Symposium on Air Cushion Technology, Ottawa, Canada. January 1977.

12. Environmental Protection Agency Report 550/9-77-450.

APPENDIX A

A.1 SUMAC/ACV OPERATIONS

A.2 LACV-30 OPERATIONS

APPENDIX A.1 SUMAC/ACV OPERATIONS

Date	Operation
December	
1-11	Outfit SUMAC and ACV with R&D instrumentation. Operate out of Base St. Louis. Run open water checkout runs in Mississippi River. Resolve initial problems such as ACV diesel engine blower malfunction. Prepare for transit to Peoria.
12	Underway in p.m. Barge on hip. Overnight at Alton.
13	Ice gorge at mile 30.6, Illinois River. Overnight at Kampsville.
14	Heavy ice. Barge towed astern. Overnight at Beardstown.
15	Barge on hip. Arrive late at night, ANFAC, East Peoria
16	Arrangements for SUMAC while at ANFAC.
17	Moor SUMAC barge for winter operation
18	Off
19	ACV skirt inspection at Pekin boat ramp
20	Attempt ballast. Crane snowed out.
21	Ballast ACV. Trim level
22	Secure ACV for Christmas
23-28	Off
29	SUMAC alone open water test, Peoria Lake
30	SUMAC-ACV open water in Peoria Lake
31	ACV not hovering properly - no operations

Date	Operation
January	
1	Off
2	Off
3	Grade Beaching Ramp
4	Beach ACV, skirt change
5	Skirt change
6	Retrieve ACV
7	Confer on skirt problems
8	Off
9	Ballast to 1.1 PSI
10	Beach ACV, skirt change, retrieve ACV
11	Break clear ice, near Army Corps pier
12	Beach ACV, repair
13	Repair, retrieve ACV
14	Operate in Peoria Lake
15	Off
16	Grade ramp, beach ACV
17	Repair skirts, main engine oil leak
18	Repair engine
19	Repair engine
20	Retrieve ACV
21	Operate in Narrows
22	Off

Date	Operation
January	
23	Beach ACV, repair, operate McCluggage Bridge
24	SUMAC light boat
25	Beach ACV
26	On beach
27	On beach
28	On beach
29	On beach
30	On beach, skirt liners arrive
31	On beach, install liners

Date	Operation
February	
1	Install liners
2	Install liners
3	Install liners, retrieve ACV
4	Operate 17 miles in Peoria Lake
5	Beach ACV, inspect, repair, retrieve
6	Assist towboats in Peoria Lake. Overnight IVY Club
7	Break clear ice, Convoy Ops, SUMAC & ACV limits reached
8	Beach ACV, repair
9	Repair
10	Retrieve ACV
11	Operate near McCluggage Bridge
12	Off
13	Beach ACV, repair
14	Repair ACV
15	Repair ACV
16	Repair ACV
17	Repair ACV
18	Repair ACV
19	Repair ACV
20	Off
21	Retrieve ACV, operate Detwiler light
22	Beach ACV
23	Repair ACV

Date	Operation
February	
24	Repair ACV
25	Repair ACV
26	Repair ACV
27	Retrieve ACV, deploy to Havana and overnight there
28	Operate to LaGrange Lock and Dam. Towboat assists. Beardstown overnight

Date	Operation
March	
1	Transit back to ANFAC
2	SUMAC rupture fuel tank
3	Clean up oil spill
4	Clean up oil spill
5	Off
6	Beach ACV, repair; one segment, retrieve ACV
7	Operate with towboat Jesse Brent
8	Return ACV to Mackley Ace, Inc. at Peoria Lock and Dam

APPENDIX A.2 LACV-30 OPERATIONS

Date	Operation
January	
1-2	Holiday.
3-5	Crew returns from leave
6	Cold weather modification
7	No operations
8	No operations
9	Maintenance, operate Peoria Lake, 2 engines down
10	Maintenance fuel system and rudder cable
11	Maintenance auxiliary power unit and port engines
12	Maintenance lift fan and #1 engine, Bell Canada Representative arrives
13	Maintenance pitch control and port engine
14	Maintenance port engine
15	Maintenance port engine. Run up
16	Maintenance skirt. Fuel control problem
17	New fuel control installed
18	Identify fuel control problem
19	Fuel leak #2 engine. Run fuel line
20	Maintenance #2 engine and fuel system
21	Maintenance #2 engine and fuel system
22	Maintenance #2 engine. Operate Peoria Lake. Starboard pitch casualty
23	Maintenance starboard dome. Defroster prod.

Date	Operation
24	Dome repair attempt
25	Maintenance routine. Bell Canada Representative departs
26	Maintenance, routine. Replacement dome delayed by weather
27	Awaiting dome
28	Install starboard dome. Run up
29	Run up. Starboard pitch problem
30	Disassemble starboard pitch control
31	Reassemble starboard pitch control. Bell Canada Representative arrives

Date	Operation
1	Maintenance starboard side. Operate Peoria Lake. Towboat assist
2	Ballast to replace swing crane
3	Operate Lower Peoria Lake. Maintenace lift fan and starboard pitch
4	Maintenance lift fan and #1 engine. Starboard side vibration
5	Off
6	Operate Peoria Lake. Repair skirt system
7	Replaced and balanced both propellers and domes
8	Operate in Peoria Lake
9	Operate in Peoria Lake
10	Operate in Peoria Lake. Towboat assist. Test magnetometer
11	Operate in Peoria Lake. Ice Survey
12	Off
13	No operations - blizzard
14	Operate in Peoria Lake
15	Operate in Peoria Lake. Ice Survey
16	Round trip to mile 100 of Illinois River
17	Round trip to LaGrange Lock and Dam (mile 80)
18	No operations - holiday routine
19	No operations - holiday routine
20	No operations - holiday routine
21	Maintenance. Skirt repair
22	Operate in Peoria Lake. Ice survey
23	Transit to mile 56. Overnight at LaGrange Lock and Dam

Date	Operation
February	
24	Transit to Alton (Mississippi River) and return to and overnight at Largo
25	Transit back to Peoria Lock and Dam
26	Maintenance. Scheduled.
27	Maintenance skirt (Lifted craft)
28	Maintenance. Bow fingers replaced. Keep bag repair

Date	Operation
March	
1	Transit to Kankakee River (Illinois, mile 270). Break one mile of Kankakee
2	Break second mile of Kankakee (to County line bridge)
3	Maintenance, general. Port propeller rigging
4	Maintenance, general. Snow ramp built
5	Rebreak lower river. Cross road. Maintenance, general
6	Maintenance, general
7	Maintenance. Replace port propeller. Skirt repair
8	Operate by bridge. Chain saw ice. No success
9	Crane break ice by bridge. Operate in afternoon. Small area broken
10	Operate near bridge
11	Operate above bridge
12	Operate in river
13	Operate in river
14	Maintenance. Skirt repair
15	Maintenance. Skirt repair
16	Operate up to railroad bridge
17	Operate in river. Cross road. Rebreak lower river. Ice flows
18	Transit back to Peoria Lock and Dam
19	Off
20-on	Test secured. Awaiting word to disassemble LACV-30

APPENDIX B

HULL SURVEY REPORT OF USCG SUMAC (WLR-311)

HULL SURVEY REPORT OF USCGC SUMAC (WLR-311)

13/14 MARCH 1978

by

JON R. BUCK

GENERAL

The USCGC SUMAC was used as the tow boat to push the experimental air cushion vehicle icebreaker RIVER GUARDIAN during test and evaluation through the 1977-1978 winter ice season. The SUMAC started operations with the RIVER GUARDIAN at St. Louis on December 1, conducting tests on the ACV icebreaker ftom that time until testing was terminated at Peoria Lock and Dam on 9 March. The SUMAC returned to St. Louis arriving on 11 March.

This Hull Survey Report presents the results of the hull inspection to determine what damage was caused to the vessel as a result of the ice-breaking operation. The inspection was conducted on 13 and 14 March at St. Louis Ship Yards, 611 East Marceare Street, St. Louis, Missouri.

REFERENCES

(a) CGC SUMAC, Booklet of General Plans, 8/12/70, DRW No. 179 SP-0103-4.

(b) Record of the Ship Structural Evaluation Board for USCGC SUMAC (WLR-311), Second Coast Guard District, 3 - 6 October 1977.

BACKGROUND

It was determined before the testing of the ACV icebreaker that the SUMAC would require some modification to the hull to minimize the potential of ice damage. The boat was dry docked at Mainstream Shipyard and Supply, Inc., Greenville, Missouri, to complete these modifications. The following is a list of these modifications:

Modifications to USCGC SUMAC for Icebreaking Operations

1. Installed ice fence deflectors around Skin Cooler 3/8 inch plate inboard and outboard 9 inches high between frames 24 and 45.
2. Installed a "V" shaped 3/8 inch plate ice deflector on keel between and ahead of frames 22 to 24 skin coolers (small "V").
3. Installed a large "V" shaped 3/8 inch plate ice deflector from keel out to knuckle from frame 48 to frame 56.
4. Installed 6 ice knives of 2" x 14" x 30" plate at frame 54.

NOTE: See reference (a) for locations.

The ice fences, Item 1, were installed to afford some protection to the skin cooler which protruded below the hull. These fences were installed longitudinally along the sides of the cooler. The small "V" ice deflector, Item 2, was installed between the port and starboard cooler to prevent ice chunks from being caught or jammed into the keel area between the coolers.

The large "V" ice deflector was designed and installed to sweep the ice outward and away from the flanking rudder, props and steering rudder. Both the small and large "V" deflectors have holes cut in them to minimize added drag to the boat.

The installation of the large ice knives, Item 4, was also intended to minimize the potential of ice hitting the critical appendage in the stern area.

During the dry docking at Greenville a thorough hull survey was conducted. Hull plate thickness was measured and it was determined that some locations had as much as 54.7 percent reduction. It was decided to reinforce these locations because of the potential of damage in icebreaking operations. The addition of a 3/8 inch plate was welded over the hull in the area of bow frames 10 to 18.

A representative sample of the critical plate thickness measurements are included in this report. (See reference B for details.)

Critical Plate Thickness Where Reinforcement was Required

Location	Strake	Frame	Design	Test	Red. In.	% Reduction
Port	Keel	17	.375	.170	.205	54.7
Port	Keel	17	.375	.285	.09	24.0
Port	Keel	21	.375	.29	.085	22.7
Port	Keel	23	.375	.24	.135	36.0
Port	Keel	24	.375	.24	.135	36.0
Starboard	Keel	13½	.375	.275	.10	26.7
Starboard	Keel	17	.375	.195	.18	48.0
Starboard	Keel	23½	.375	.270	.105	28.0
Starboard	Keel	25	.375	.265	.11	29.3
Port	A	16½	.375	.265	.11	29.3
Port	A	17½	.375	.25	.125	38.3
Port	A	18½	.375	.265	.110	29.0
Port	A	19½	.375	.235	.14	37.3
Port	A	20½	.375	.245	.13	37.7
Port	A	21	.375	.245	.13	37.7
Port	A	21½	.375	.280	.095	25.3
Port	A	22½	.375	.380	.095	25.3

HULL SURVEY RESULTS

The following is a listing of the damage to the SUMAC which appeared to be the result of the test and evaluation of the ACV icebreaker operation. The results are presented by areas of the hull, i.e., Starboard, Port, Stern and Bow.

STARBOARD

1. Scoop valve guard - severely damaged--must be replaced.
2. Large "V" ice deflector - bent all along its length. Broken off at knuckle. Center point crushed in against hull.
3. Skin cooler ice fence - only slightly dented.
4. Small "V" ice deflector - severely dented and crushed at center point.
5. Slight bend in inboard pipe of skin cooler at a point about mid-ship.
6. Slight dent in fairing on leading edge of skin cooler (could have been previously damaged before icebreaking operations).

PORT

1. Scoop valve guard - severely damaged-- must be replaced.
2. Large "V" ice deflector - moderately bent along length. Severely bent on outboard side.
3. Fracture of fuel compartment (Port aft) at a point 3 inches along the weld of the large "V" ice deflector, approximately 18 inches in from the knuckle (after the first cutout hole of the ice deflector). The fracture is approximately 1/2 inch long. This fracture appeared to be in the heat sensitive zone of the weld

and was caused by the tearing away of the ice deflector in that location.

4. Slight denting of fairing of the skin cooler near keel (possibly from previous damage).

5. Dent in hull plating and stiffners between frames 2 - 3 and 3 - 4 above waterline about 1 foot below deck level. No visible paint scratches on outside but flaked paint on inside indicating a new dent. That compartment had been newly painted at Greenville.

STERN

1. Port Flanking Rudder - missing, broken off flush with hull.
2. Keel Flanking Rudder - missing, broken off flush with hull.
3. Keel Propeller - slight dents in two blades, repaired in place.
4. Starboard Propeller - severely dented--must be replaced.
5. Starboard Steering Rudder - missing, rudder post broken off about 2 inches below hull bearing.
6. Keel Steering Rudder - rudder post bent to port about 4 degrees bend at hull point.
7. Port Steering Rudder - rudder post bent to starboard slightly about 1 degree.
8. Port and keel rudder restraining chains missing.

BOW

1. Starboard Knee - rubber damaged at bottom, steel retaining bracket ripped off on both sides up from the bottom for about 3 feet on inboard side and 1 foot on outboard side. Steel retaining bracket dented at several locations above water line (probably due to collision with ACV at Pekin, Illinois.

2. Keel Knee - rubber damaged slightly at bottom. Both sides of retaining bracket bent.

3. Port Knee - steel retaining bracket on outboard side missing for about 8 feet up from bottom. Inboard side torn free and rolled back about 3 feet up from bottom.

4. Four anodic zincs missing on bow.

GENERAL OVERALL VIEW

1. Bow and bottom paint scoured down to bright metal.

2. Waterline region scoured paint down to bright metal about 1 foot wide.

3. Paint scoured to a slight degree from knuckle to waterline.

4. Stern area has some paint scouring.

5. Occasional slight dents in hull not necessarily due to ice-- could have been there previously.

SUMMARY

There was considerable damage to the ice deflector "V"s both the small one in front of the skin cooler and the large one in the stern. It is doubtful if the fuel tank would have been damaged if the ice deflector had not been torn away. The large 2" x 14" x 30" ice knives were undamaged.

The steering rudders were most likely damaged in turning and backing down maneuvers. It appears that when the SUMAC instituted a turn in heavy ice that large plates of ice would slide under the hull and place a large athwartships load on the rudder post. As indicated by the port rudder post being bent inboard to starboard and the keel rudder unprotected by the

missing starboard rudder being bent to port. It appears that loads in turns might be greater than loads from backing down provided that the rudders are centered during the backing down maneuver. The starboard rudder had been broken off three times during the ACV icebreaking operations. One time was definitely during a turn to port in heavy ice (18 inches of uniform thickness plate ice) causing the starboard stern of the SUMAC to slide up against the ice field.

The starboard and keel propellers were most likely damaged when they hit the loose starboard rudder. This rudder was restrained by the rudder chain and was pushed into the propeller when the boat was backing down in ice.

It is interesting to note that the ice fences longitudinally along the skin cooler were not damaged. It is difficult to determine if the forward small "V" afforded any additional protection to the skin coolers.

The cause of the dent in the hull on the port forward location is undetermined. The crew members of the SUMAC were interviewed and the time and event causing this damage could not be verified. On one occasion when the tow boat THOMAS was taking on portable water at ANFAC, Peoria, it ran into the SUMAC which was moored at the facility. It is possible that this dent could have occurred at this time.

The damage to the towing knees appeared to be caused by ice between the ACV and the boat. As the ACV/SUMAC moves through an ice field the large plates of ice are pushed down by the cushion pressure, they pass under the craft and emerge again from the cushion near the knees of the SUMAC. However, the SUMAC had operated in heavy ice without the ACV on its bow. It is understood that the SUMAC encountered heavy ice on its

return trip to St. Louis and on several occasions had to back and ram the ice to get through. It is possible that the major damage to the knees could have occurred during the non-ACV attached time. During periodic docking operations of the ACV the SUMAC's knees could be observed. During the icebreaking test and evaluation operation it was noted that some damage had occurred to the knees but, that it did not appear to be so extensive.

The damage to the scoop valve guards is understandable as they protrude from the side of the hull and are particularlly vulnerable. They are, however, a minor item. The scouring of the paint was expected and is not greater than expected. The loss of the sacrificial anodic zinks was also expected as they are in a vulnerable area for ice impact.

RECOMMENDATIONS

The following items are included as possible recommended modifications to the hull of the SUMAC or other similar boats to be used in ACV icebreaking operations in the future:

1. Install ice deflector posts approximately 4 inches in diameter, 2 feet long, adjacent but outboard to the steering and flanking rudder posts. Each post should be gussited to reduce stress concentration. This post will help to protect the rudders during turns in heavy ice.
2. Install, where clearance permits, gussets at the top of each rudder post to distribute the load and reduce stress concentrations.
3. Install more ice knives to protect rudders and skin coolers in lieu of "V" ice deflectors. The knives could be positioned in a "V" shape

along the hull to assist in moving the ice chunks outboard. This technique reduces appendage drag over the "V" deflector now used but provides protection from ice.

4. Beef up the fairing to the leading edge of the skin coolers. The small "V" between the coolers need not be installed.
5. Place a bow modifier between the SUMAC and the ACV. This modifier would act to displace the ice to the side of the boat instead of pushing in beneath it. The bow would act like a plow. It is recognized that an ice bow was used on the SUMAC before. The recommended modified bow for ACV operation would not be of such size and bulk.

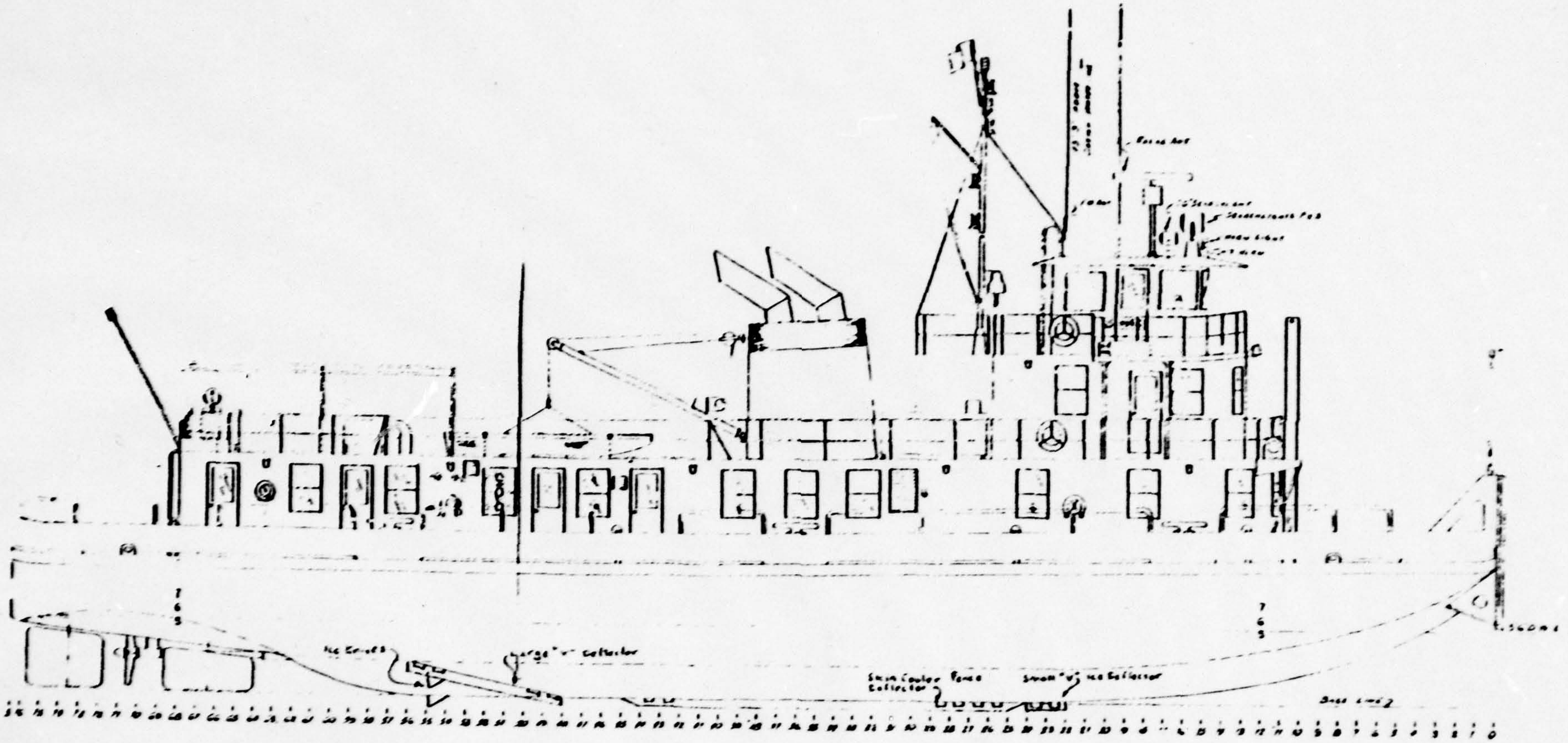


Figure B-1 SUMAC Hull Diagram

APPENDIX C

SEGMENT REPAIR SUMMARY

RIVER GUARDIAN

INTRODUCTION

During the project the skirt system of the RIVER GUARDIAN suffered repeated failures due to its segments being torn. This section presents the specifications for segment material and the liners that were eventually employed to reduce the failure rate. It also examines the segment damage that occurred throughout the project. Major events that occurred concerning the skirt system during the project are listed in Table C-1. A summary of skirt maintenance procedures is provided in Table C-2.

THE SEGMENTS

The skirt system was made up of 96 individual cone-like segments suspended from 26 steel frame trays which could be slid out from under the craft for segment inspection, removal and replacement. Two segment sizes were employed. One size fit the straight frames while the other size was used on the curved corner frames. Both segment sizes, however, were of the same design with only minor dimension changes necessary to accommodate the frame variation. Figures C-1 and C-2 provide diagrams of a segment.

The segments were made of a flexible 60 oz/sq yd material consisting of rubber with an inner base type nylon weave. Due to the harsh ice environment, the segments suffered repeated damage necessitating frequent repairs. In an effort to reduce segment failure and insure a more reliable cushion for the ACV, a 24 oz/sq yd liner of nylon weave reinforced polyvinylchloride (PCV) was introduced in the

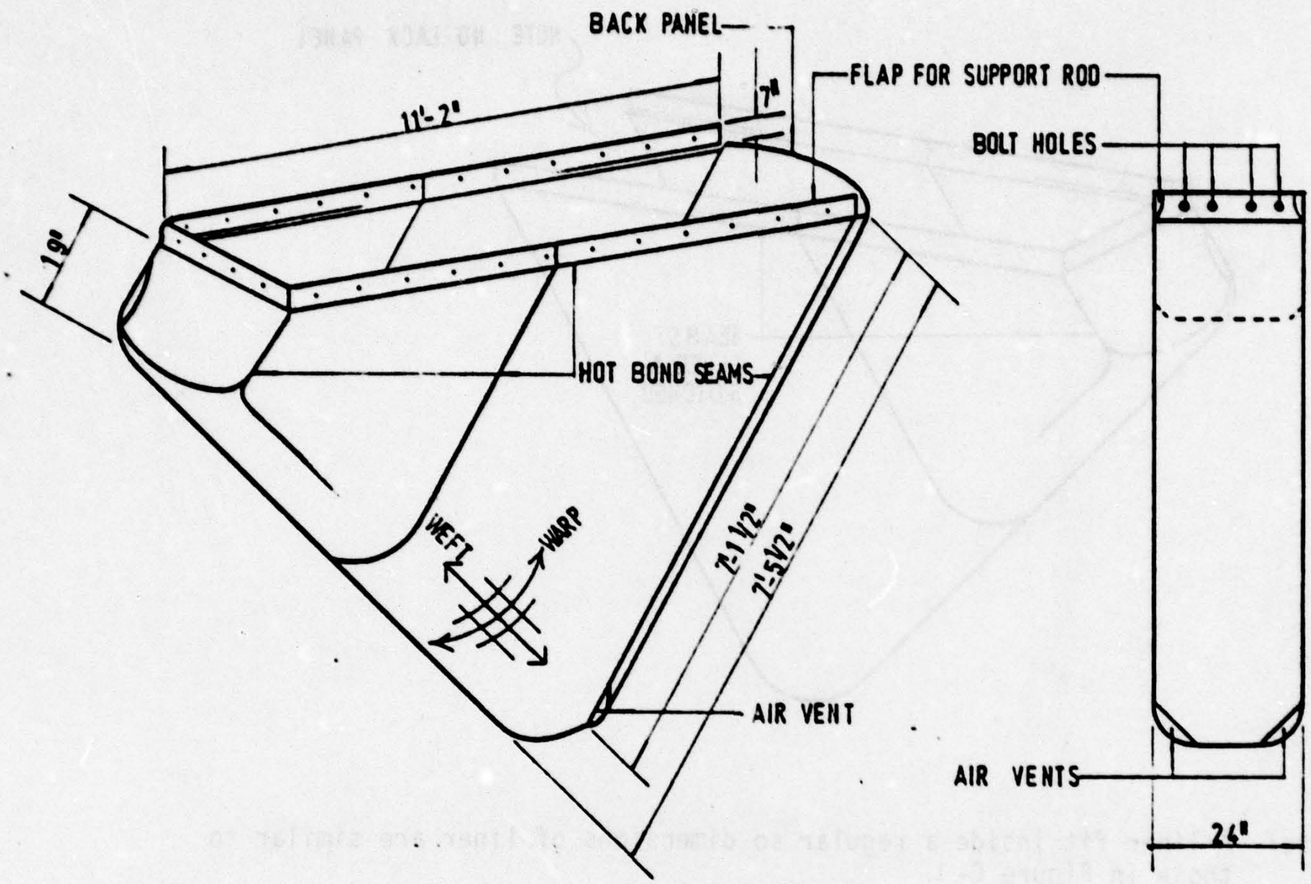
DATE	EVENT OR OBSERVATION
12-12-77 - 1-5-78	Craft's "B" side served as bow
1-6-78 - 3-8-78	Craft's "C" side served as bow
12-19-77	Craft beached at Pekin, Illinois. Skirt inspection provided first evidence of segment damage. Back panels on segments were found ripped. Tears began at the base of individual segments and continued up the back panels adjacent to their hot bond seams. Not considered seriously damaged.
2-3-78	Tire fender system installed over bow of ACV covering trays C1, C2, C3. PVC liners installed inside segments of trays +C, C-1, C-2, C-3, and -D.
2-8-78	-C tray frame discovered bent between -C1 and -C2 segments. Overnight mooring in icefield thought to be responsible.
2-13-78	PVC liners installed inside segments of trays -C & +D
2-21-78	Tire fender system extended to cover trays +C and -D External protection patches installed on segments in trays +C and -D. By this date all segment back panels had been removed from trays B4, -C, +C, C1, C2, C3, -D, +D
3-8-78	Final beaching of ACV at Peoria Lock & Dam site

Note: Back panels on segments were designed to prevent skirt system from scooping up ice chunks. They were not considered of major importance in the skirt system and so their ripping was not considered serious. Later in the project, the back panels were cut out of many segments because they were ripped. They became useful as repair patches.

Table C-1 Major Events Concerning Skirt System on RIVER GUARDIAN

EVENT	TIME	MEN	COMMENTS
Beaching of ACV	45 min	6	This is an average beaching operation considering the repair pad to be adequate, but location and support equipment not necessarily designed for this purpose.
Removal of Spray Skirt	5 min	3	Removal of only 1/4 of the total spray skirt
Pulling of Straight Segment Tray	5 min	3	Pulling of straight side segment tray for inspection using a winch truck or Caterpillar tractor
Pulling of Corner Segment Tray	10 min	4	Pulling of corner segment tray for inspection. Requires 55 gal. oil drums to support the weight of the segment tray. Winch truck required.
Removal of Segment	15 min	4	Removal of a segment from one of the trays. This includes removal of the reinforcing steel straps.
Installation of Segment	15 min	4	Install new segment - bolted in place
Recouple Tray	10 min	4	Push tray back in place and secure

Table C-2 Summary of Skirt Maintenance Procedure



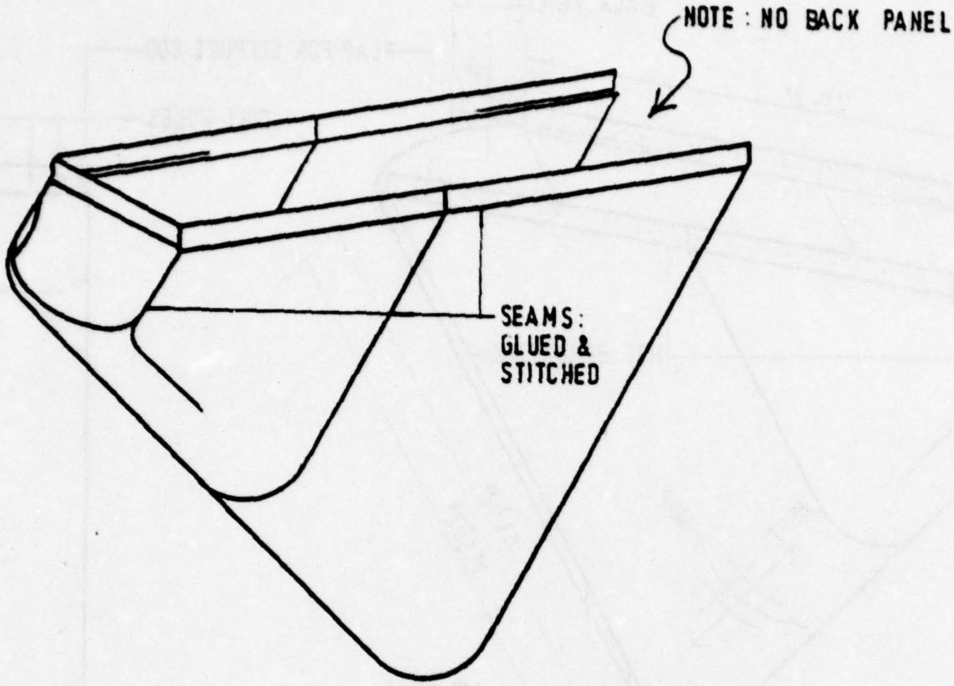
Segment Statistics*

Material	Rubber
Color	Black
Material Weight	60 oz/sq yd
Tensile Strength (Warp)	450 lbs/sq in
Tensile Strength (Weft)	350 lbs/sq in
Tear Strength-Birds Wing Test**	90lbs (Warp & Weft)
Base Weave	Nylon
Manufacturer	Avon Co., England

* As supplied by Mackley Ace (USA), Inc. - See Reference 9 for results of tests run by VPI University

** British Standard Tear Test

Figure C-1 RIVER GUARDIAN Segment Diagram



Note: A liner fit inside a regular so dimensions of liner are similar to those in Figure C-1.

Liner Statistics*	
Material	"Polymit 19" PVC coated polyester
Color	Red
Material Weight	
Base	9 oz/sq yd polyester
Finished	23/24 oz/sq ud
Tensile Strength**(Warp)	800+ lbs/sq in
Tensile Strength (Weft)	800+ lbs/sq in
Tear Strength***(Warp)	185 lbs
Tear Strength (Weft)	250 lbs
Coating Adhesion****	20 lbs/sq in
Cold Crack*****	-27/-30°C

* As supplied by Mackley Ace (USA), Inc.
** British Standard Test - BS3424, 1961 Method 6A
*** British Standard Test - BS3424, 1961 Method 7A
**** British Standard Test - BS3424, 1961 Method 9A
***** British Standard Test - BS3424, 1961 Method 10

Figure C-2 RIVER GUARDIAN Liner Diagram

bow. These liners were of similar design to the rubber segments and fit conveniently inside 21 bow segments. Figures C-1 and C-2 provide the specifications for both the rubber and PVC segments.

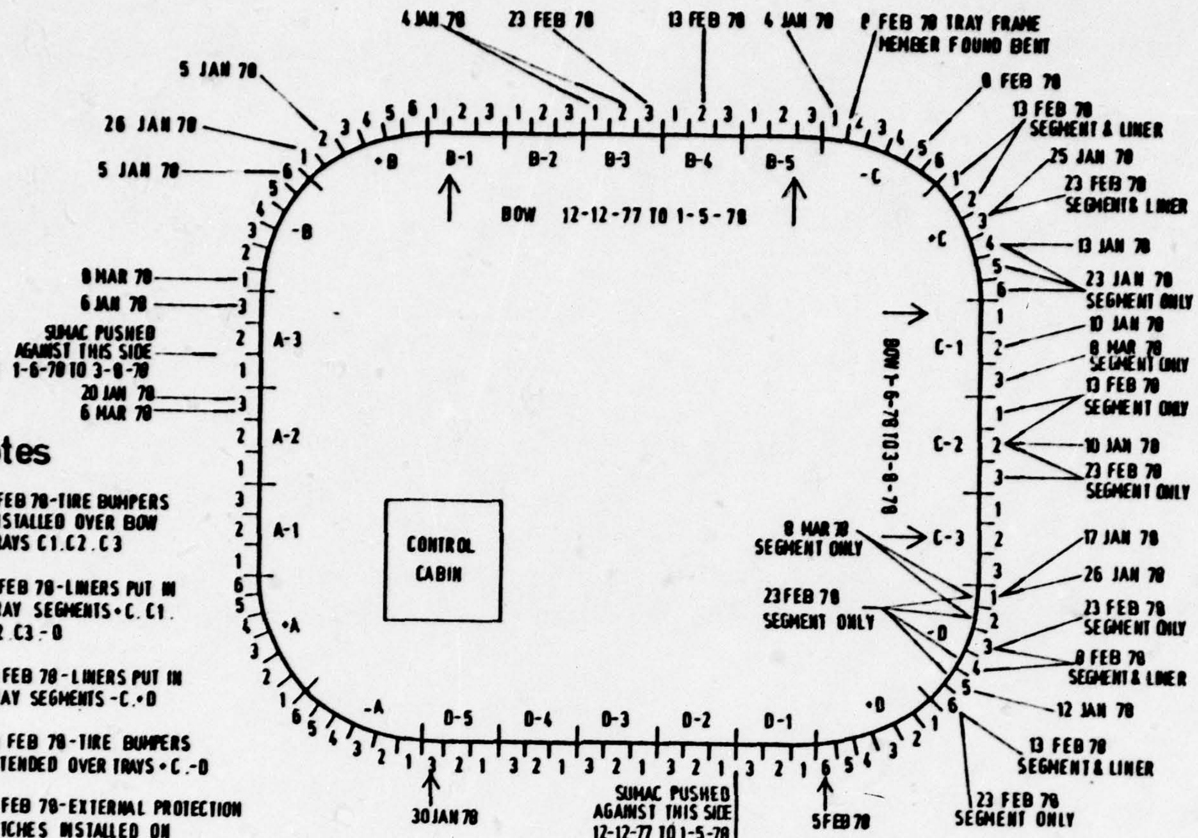
Originally, the entire skirt system of the craft was covered from view with a lighter-weight spray skirt made of nylon reinforced rubber. Its purpose was to prevent water spray created by the craft from spilling out and freezing on the deck of the ACV during operations. Unfortunately, the ice quickly destroyed this skirt.

At one point in the project, it was suggested that something should be provided to prevent sharp ice from puncturing the segments. A fendering system was, therefore, fabricated out of old automobile tires and suspended over the bow of the ACV. Whether the tire fendering system directly helped to prevent or reduce segment failure was difficult to ascertain. The tire system was implemented at the time the liners were introduced but, even with these modifications, the segments failed.

REPAIR

The 60 oz/sq yd segment material proved to be no match for the ice conditions encountered on Peoria Lake. Segments, mainly in the bow region, were torn severely and required replacement. The rate of segment failure was totally unanticipated and, therefore, the supply of spare segments was quickly exhausted. To order and manufacture additional segments would have delayed operations until spring; therefore, Mackley Ace personnel set about the task of repairing the damaged segments in the field. Extremely damaged segments were cut up to provide patches for repairable segments. Pop rivets were originally used to secure

patches and mend minor tears. However, these soon ripped out. Eventually, patches were glued on and then stitched by a commercial company. This produced a stronger repair job than the pop rivet method, but a good number of segments repaired in this manner failed also. Finally, the PVC liners were placed in the bow segments, and outside segments in +C and -D trays were reinforced with a pop riveted patch along their most vulnerable front area. During subsequent operations, the outer segments on the bow failed with their reinforcing patches being torn off, thus creating holes from which tears developed. The liners, on the other hand, maintained their shape, thus enabling the craft to continue operations and successfully return to port. Very few liners failed. Figure C-3 provides a detailed summary of segment damage dates.



Notes

1. 3 FEB 78 - TIRE BUMPERS INSTALLED OVER BOW TRAYS C1, C2, C3
2. 3 FEB 78 - LINERS PUT IN TRAY SEGMENTS + C, C1, C2, C3, - D
3. 13 FEB 78 - LINERS PUT IN TRAY SEGMENTS - C, + D
4. 21 FEB 78 - TIRE BUMPERS EXTENDED OVER TRAYS + C, - D
5. 21 FEB 78 - EXTERNAL PROTECTION PATCHES INSTALLED ON SEGMENTS IN TRAYS + C, - D

Segment Damage Diagram
For River Guardian
Figure C-3

APPENDIX D

ANALYSIS OF PROJECT OBJECTIVES

INTRODUCTION

It is much more desirable to make direct measurements during a test and evaluation program than to collect opinions. Numbers can be interpreted much more clearly and further processed to yield and justify more far reaching conclusions. The problem is to identify what quantities can be measured and what is to be done with the data after the test.

The objectives of the test and evaluation are not directly measurable as they are stated. Each objective must be carefully analyzed and considered, then reduced to a measurable objective. It is these newly "reduced" objectives that will be measured during the test and evaluation.

The danger of this approach is that the essence of the original objectives may be lost. The following paragraphs address each of the objectives from the Test Plan for ACV Icebreaking and present the logic that results in the test measurements and individual tests (Reference 8).

Though this logic was originally employed for the barge-type ACV, its essence holds for the self-propelled ACV also.

OBJECTIVE 1 - FACILITATING MARINE COMMERCE BY ACV ICEBREAKING

Marine commerce may be broken down quite clearly into many elementary components; e.g., tonnage, cargo type, cargo value, transit time and so forth. One of the uses of these types of data is to assess economic impact, i.e., numbers are generally put into economic models that generate numbers describing revenue, rate of return, etc. It is far beyond the scope of the test and evaluation to assess the economic impact upon the towboat industry or the State of Illinois of the ACV icebreaking capability of the Coast Guard. But, it is desirable to obtain information on how ACV icebreaking affects the elementary components of marine commerce in the Illinois/Mississippi River System.

Ideally, the effect of ACV icebreaking upon commerce would be measured in the following way: over a given ice period, two identical Illinois River systems would be required, both having the same ice condition and towboats operating. The ACV icebreaker would operate in <u>one</u> of the two systems. Then all of the numbers describing commerce (number of towboats each day, tons on each tow, transit time, etc.) would be collected in each system. They would be compared and the difference would be due to the ACV icebreaker, the only difference in the two systems.

The above approach works well with models or with full-scale systems where duplicates are available. The Illinois River and its attendant commerce are not so easily duplicated. In lieu of this

impossible, ideal approach, several approximate methods will be used. They all will, in some way, attempt to emulate the results of the ideal approach but will fall short of the ideal due to their inherent limitations.

The first approach which approximates the ideal is to go back to the historical data from past years kept by the Army Corps of Engineers. Attempt to find the same weather conditions as this year over the same period of operation. In addition, establish that it was attempted to move the same amount of commerce. Then, compare the measure of commerce for this year (tonnage, transit time, etc.), with the ACV icebreaker present, and the historical year. The difficulties with the approach are numerous; e.g., it is difficult to repeat the same weather patterns, the economic health of the country dictates the potential barge traffic and the economy has been erratic recently, but barge traffic has been increasing. Even with these problems, a comparison can be made between the two sets of statistics and the differences between them attributed directly or indirectly to the ACV icebreaking.

The Army Corps of Engineers compiles voluminous statistics on the Illinois Waterway (as well as others). Reaching back into their data may provide a further means of comparison of like winters even though the daily profiles of temperature are not the same.

It may prove necessary to manipulate the data to obtain the measures of commerce that are demanded. Certainly unique or different quantities such as degree-days* of icebreaking could be generated from past data and capability to do so is at hand.

Another experimental approach is to intentionally leave a given reach of river unbroken (say five miles). Let a commercial towboat transit this reach and measure the time to transit and the fuel comsumed during the transit. Next, let the towboat transit a broken (by the ACV icebreaker) reach of the same distance and make the same time and fuel measurements. The differences in fuel consumption and transit time are then directly attributable to the air cushion vehicle icebreaker (the ice conditions being equal over the two reaches of river).

A more subjective approach is to interview experienced towboat captains on the river and ask them to assess the effect of ACV icebreaking upon measure of commerce, transit time, tonnage, etc. In addition, the ice damage suffered could be compared to a like winter without ACV icebreaking capability. This approach can provide the flavor of success or failure but provides no measurable quantity.

All of these approaches, as can be seen, fall short of measuring directly the effects of ACV icebreaking upon commerce, but, in the aggregate, the three approaches (1) finding a comparable year, (2) running the towboat with and without icebreaking, and (3) interviewing experienced towboat operators will supply a reasonable measure of the effect of the icebreaking upon commerce.

OBJECTIVE 2 - DEVELOP ACV ICEBREAKING PROCEDURES

Icebreaking procedures can be broken down into tactics and strategy. An example of tactic is the speed and number of passes used to break the ice near a dam. The method of deployment, responding to a boat

stuck in the ice or continually breaking the channel, would be a strategic decision.

The guide presently available to assist in developing techniques to break ice is the experience of the Canadian Coast Guard and the Icebreaking Annex (X) of the Second District OPLAN. The area of employment, (river versus open water), the requirements of ice breaking, and the great physical differences between the Canadian Craft and the SUMAC-ACV Bow make it necessary to start at a basic level.

Consider some of the differences in hardware and requirements. The Air Cushion Vehicle bow pushed by the Canadian Coast Guard Icebreaker ALEXANDER HENRY was less than one tenth (1/10) the displacement of the ALEXANDER HENRY. The CGC SUMAC is closer to one fifth (1/5) of displacement of the Air Cushion Vehicle bow that she will push. The Canadian icebreaker is a deep draft vessel with screws well below the water surface unlike SUMAC which is more flat bottomed and shallow draft and hence more subject to ice damage. In addition the Canadians had to break a channel in clear ice where the requirement on a river is to break the channel with all of the problem of bends, obstructions and refreezing after the towboats have passed through.

The increasing experience of both the Air Cushion Vehicle contractor and the Coast Guard operating personnel will enhance the development of icebreaking tactics. Some of the items to be considered are the number of passes in a given area, speed, jockeying controls, degree of control, and limits of all of the above. It is not apparent at

this writing what many of these limits are or what the behavior of the vessel is going to be in ice. The test runs will be very flexible so that procedures that show promise can be further explored and those that don't will not be continued.

The initial familiarization trails with SUMAC and ACV bow will provide a great deal of information on controlability, speed and other limiting factors. At that time those parameters can then be bounded in the test series. The initial ice operation will again provide further information which will narrow the procedures to be attempted. This will be done during the operating period as soon as practical.

Ultimately, probably more important than the tactics or procedures used to physically break the ice is the strategy of deployment and usage of the Air Cushion Vehicle icebreaker. Icebreaking as viewed in the past by the Second Coast Guard District has been in a response role, much, like SAR. If a towboat was stuck in the ice, the Coast Guard would assist him.

The Air Cushion Vehicle icebreaker offers the chance to keep a much larger area of the river open to traffic if used on a continuing basis along with a coordinated effort of the towboat operators. If too many miles of river are "bitten off", then the icebreaking will be ineffective when the river refreezes. The convoy approach of escorting several towboats up or down the river is another method

of deployment that should be considered. This may be the only way to handle an area that gorges like Peoria Lake.

A final area of consideration is an ice clearance. The ice that is broken must either be pushed aside or further downstream. If it is pushed aside, it may ultimately lead to gorging in a narrow or restricted channel. If carried downstream, ice jams may occur at locks and dams. This is especially critical at dams where the possibility of losing the whole river pool exists if the dam is breached.

The strategic choices depend upon the weather. If the winter is mild, a large segment of the river can be broken on a regular basis by the Air Cushion Vehicle icebreaker. The towboats would then keep it clear with periodic transits. If the winter is more severe, assisting, escorting, or convoy techniques may be used. Commercial towboats must be used to clear dams in order that they not be breached.

OBJECTIVE 3 - COST EFFECTIVENESS OF ACV'S

It is necessary to define and bound cost effectiveness in the context of the test and evaluation. First, since the ACV platform is leased with an option to buy, it is not clear what the first cost is. The maintenance and life cycle costs are not presently known. Therefore, at this juncture, dollar cost figures are uncertain, but is still possible to establish relative and absolute cost figures for certain aspects of ACV icebreaking and these will be a good point

of departure for a future comparative costing study.

One of the most obvious benefits found by the Canadians in their icebreaking operation was the fuel savings in terms of gallons of fuel per square mile of ice broken. This quantity may be determined during the test and evaluation and be an input in the future for total operating cost of an ACV-pusher icebreaking combination. This data may then be compared with any conventional icebreaker to compare the fuel costs. The ACV icebreaker fuel consumption includes both the pusher vessel <u>and</u> the ACV.

Further, ACV costs may be assessed in the areas of damage and maintenance. All repairs, both man hours and replacement parts, are costs. These will be accumulated over the duration of the test and compiled. These data can then be used as input for life cycle costing where the life of a component must be considered. These data, again, are only a crude estimate since a very small portion of time and a single vehicle are going to be used, not a fleet which gives a much better statistical sample. The objective in determining costs is to measure what you can accurately and consider all other aspects for inclusion in a costing model.

The second part of cost-effectiveness is effectiveness. This may simply be measured as square miles of ice broken per hour. The quality of the broken ice is not a measurable quantity. It can be described in terms of size of ice pieces or the fraction of the channel

cleared and some more specialized ice descriptions. If the broken ice is in such large pieces that it requires a second pass to make the channel navigable, this effectively reduces the square miles of ice broken per hour.

Another complexity of effectiveness is the disposition of the broken ice. It ultimately must pile up on the side of the channel, flow downstream or melt. There may prove to be a limit to the effectiveness of icebreaking if gorging occurs. Further, the flushing of ice over the dams and through the locks is another limitation of the icebreaking operation. It follows that being too effective (breaking too many square miles per hour) can result in ice gorges and jams further downstream. Therefore, effectiveness is in terms of the rate at which ice is broken, but with the constraint that it may only reposition the problem further downstream.

OBJECTIVE 4 - DETERMINE TRAINING, PERSONNEL AND SUPPORT NEEDS

Each of the items in this objective are defined below in the context of this test and evaluation.

Personnel means the number, type and rate of the people necessary to operate and maintain the Air Cushion Vehicle bow.

Training means the additional training necessary for an MK (for example) to be able to satisfactorily maintain and operate the Air Cushion Vehicle bow.

Support needs are those goods and services that are not standard in the Coast Guard inventory that are necessary to adequately maintain and operate the Air Cushion Vehicle bow.

Observing the performance of the people operating and maintaining the ACV will provide the information necessary to establish the need for additional support and training. Self-propelled ACV's require operator training much like aircraft. The British Navy even has a school set up along these lines. Presently, it is assumed that the operating personnel will adapt readily to the nonself-propelled ACV, which is pushed like a barge. The operator is already familiar with the pusher vessel and the ACV bow is, therefore, the only unknown quantity. In the case of the self-propelled ACV, the operator must become familiar with the entire craft.

Maintenance of the ACV will be performed by Coast Guard personnel (when possible) supervised and trained by the ACV contractor. Their (CG) performance will reflect their skill and training. The need for non standard items such as crane service and a large beaching area will become apparent as they are needed.

OBJECTIVE 5 - DETERMINE DESIGN CRITERIA

Design criteria is taken to mean those numbers and curves which describe performance of the Air Cushion Vehicle. The basic description of air cushion icebreaking is the speed-ice thickness-cushion pressure envelope. These are influenced by power available and the platform

size. Further important engineering information includes noise levels, ACV roll and pitch attitude, ballast, and fuel consumption.

Actual operating data for a specific design provides an excellent point of departure for future design. Sizing the requirements of ice thickness determines the platform size and cushion pressure. Actual tests data can be used to verify some of the empirical laws of ACV icebreaking design. The actual icebreaking mechanism has not been adequately modeled mathematically. Any information about the physical aspects of the breaking mechanism will be a valuable input for the future. Air cushion noise levels have been a point of contention in the past. Actual measurements are needed.

In addition to the ice breaking capability of the Air Cushion Vehicle, the maneuvering characteristics are extremely important. The Air Cushion Vehicle offers no directional stability and the combination of it with the pusher vessel is an unknown quantity. Standard maneuvering tests will allow a quantification of vessel performance in turns, stopping and passing. This will allow future vessels to be designed to, or exceed these particular values of maneuverability as required by the operators.

APPENDIX E

LOCAL CLIMATOLOGICAL DATA

(National Weather Service Office, Greater Peoria Airport, Monthly Reports.)

(December 1977, January 1978, February 1978)

DECEMBER 1977
PEORIA, ILLINOIS
NATIONAL WEATHER SERVICE OFC
GREATER PEORIA AIRPORT

Local Climatological Data

MONTHLY SUMMARY

DECEMBER 1977 PEORIA, ILLINOIS

LATITUDE 40° 40' N LONGITUDE 89° 41' W ELEVATION (GROUND) 652 FT. STANDARD TIME USED: CENTRAL WBAN 014842

Date (1)	Temperature °F: Maximum (2)	Minimum (3)	Average (4)	Departure from normal (5)	Average dew point (6)	Degree days base 65°: Heating (season beginning with July 1) (7A)	Cooling (season beginning with Jan. 1) (7B)	Weather types on dates of occurrence: 1 Fog, 2 Heavy fog, 3 Thunderstorm, 4 Ice pellets, 5 Hail, 6 Glaze, 7 Duststorm, 8 Smoke, haze, 9 Blowing snow (8)	Snow, ice pellets or ice on ground at 06AM in. (9)
1	39	29	34	1	20	31	0	1	8
2	36	24	30	-3	25	35	0	1	3
3	30	12	21	-11	16	44	0	1	10
4	28	17	23	-8	18	42	0	1	8
5	32	14	23	-8	25	42	0	1 4 6 8	7
6	16	-6	5	-26	-8	60	0	8	8
7	12	-8	2	-28	-4	63	0		8
8	26	6	16	-14	15	49	0	1 8	5
9	6	-6	0	-30	-10	65	0	8	8
10	5	-10*	-3*	-32	-14	68	0		6
11	30	-4	13	-16	3	52	0		5
12	39	30	35	6	25	30	0		4
13	38	33	36	7	33	29	0	2	3
14	35	30	32	4	30	33	0	2	2
15	40	30	35	7	32	30	0	2 8	1
16	50	35	43	15	38	22	0	1 8	1
17	54*	38	46*	18	38	19	0	8	T
18	38	32	36	8	32	29	0	8	0
19	43	27	35	8	30	30	0	1 8	0
20	32	15	24	-3	18	41	0	8	2
21	21	16	19	-7	14	46	0	8	2
22	33	8	21	-5	14	44	0		2
23	34	24	29	3	20	36	0		1
24	41	15	28	2	24	37	0	1 8	1
25	17	3	10	-16	-2	55	0	8	T
26	16	4	10	-15	-1	55	0		T
27	12	0	6	-19	-8	59	0		T
28	32	7	20	-5	10	45	0		T
29	41	21	31	6	21	34	0	1	0
30	33	16	25	0	21	40	0	2 8	0
31	34	24	29	5	28	36	0	1 6 8	0
	SUM	SUM				TOTAL	TOTAL		
	940	475				1301	0	NUMBER OF DAYS	
	AVG.	AVG.	AVG.	DEP.	AVG.	DEP.	DEP.	PRECIPITATION	
	30.3	15.3	22.8	-5.2	10	154	0	≥ .01 INCH	9
						SEASON TO DATE		SNOW, ICE PELLETS	
	NUMBER OF DAYS					TOTAL	TOTAL	≥ 1.0 INCH	8
	MAXIMUM TEMP.		MINIMUM TEMP.			2498	1110	THUNDERSTORMS	0
	≥ 90°	≤ 32°	≤ 32°	≤ 0°		DEP.	DEP.	HEAVY FOG	4
	0	15	28	8		183	142	CLEAR 4 PARTLY CLOUDY 11 CLOUDY 16	

Date (22)	Precipitation: Water equivalent in. (10)	Snow, ice pellets in. (11)	Avg. station pressure in. Elev. 662 feet m.s.l. (12)	Wind: Resultant dir. (13)	Resultant speed m.p.h. (14)	Average speed m.p.h. (15)	Fastest mile: Speed m.p.h. (16)	Direction (17)	Sunshine: Minutes (18)	Percent of possible (19)	Sky cover tenths: Sunrise to sunset (20)	Midnight to midnight (21)
1	.18	2.2	29.82	25	12.5	15.1	28	W	241	42	7	8
2	.38	4.7	29.12	21	6.0	7.0	14	SW	498	80	5	7
3	.14	2.0	29.21	33	5.0	6.5	8	N	64	11	8	8
4	0	0	29.22	07	7.8	8.5	17	NE	228	40	8	8
5	.46	4.1	29.87	01	12.4	15.7	28	NW	0	0	10	10
6	T	T	29.38	28	10.2	10.7	30	NW	542	98	3	2
7	T	T	29.90	17	3.8	6.8	12	SE	425	78	5	5
8	.31	3.5	29.14	18	2.8	12.7	28	W	0	0	10	9
9	T	T	29.63	27	10.3	10.8	30	W	381	68	8	3
10	0	0	29.82	27	5.8	7.8	10	W	387	71	8	4
11	0	0	29.74	13	8.7	9.5	18	S	400	71	6	8
12	T	0	29.28	18	14.8	15.0	16	S	0	0	10	10
13	T	0	29.16	18	6.5	8.1	12	S	0	0	10	10
14	T	0	29.24	31	4.6	7.8	13	N	0	0	10	10
15	0	0	29.18	16	13.6	13.8	18	S	250	45	10	8
16	0	0	29.04	15	17.7	17.8	24	SE	247	44	8	7
17	T	0	29.78	17	17.2	18.3	28	SE	148	26	8	8
18	T	0	29.88	23	7.4	8.1	12	W	0	0	10	10
19	.30	1.1	29.08	04	7.1	8.8	14	NE	204	53	7	8
20	.21	1.2	29.09	27	16.4	17.4	24	W	0	0	10	10
21	.04	.5	29.12	27	14.8	15.2	18	W	3	1	10	8
22	0	0	29.18	19	11.3	14.0	25	S	430	77	7	8
23	0	0	29.11	21	8.1	11.5	17	S	502	90	1	2
24	0	0	29.00	23	6.0	14.9	30	NW	89	15	8	6
25	T	T	29.32	28	10.5	10.7	25	W	401	72	8	8
26	0	0	29.39	27	9.1	10.2	14	W	460	83	5	2
27	0	0	29.55	28	9.8	10.8	13	W	556	100	0	1
28	T	T	29.46	22	8.1	10.1	18	W	441	78	5	7
29	0	0	29.32	18	7.2	8.1	13	SW	470	88	4	4
30	0	0	29.38	02	4.6	5.2	8	N	435	78	1	4
31	.25	2.4	29.43	08	8.8	9.5	10	E	0	0	10	10
	TOTAL	TOTAL	FOR THE MONTH:						TOTAL	%	SUM	SUM
	2.29	21.7	29.29	23	4.4	12.0	30	NW	7862	FOR	218	213
	DEP.						DATE: 24+		POSSIBLE	MONTH	AVG.	AVG.
	0.38								17334	45	7.1	6.9

GREATEST IN 24 HOURS AND DATES: PRECIPITATION		SNOW, ICE PELLETS		GREATEST DEPTH ON GROUND OF SNOW, ICE PELLETS OR ICE AND DATE	
.93	2-3	8.7	2-3	10	3

* EXTREME FOR THE MONTH - LAST OCCURRENCE IF MORE THAN ONE.
T TRACE AMOUNT
+ ALSO ON AN EARLIER DATE, OR DATES.
HEAVY FOG: - VISIBILITY 1/4 MILE OR LESS.
FIGURES FOR WIND DIRECTIONS ARE TENS OF DEGREES CLOCKWISE FROM TRUE NORTH. 00 = CALM.
DATA IN COLS. 6 AND 12-15 ARE BASED ON 7 OR MORE OBSERVATIONS PER DAY AT 3-HOUR INTERVALS.
FASTEST MILE WIND SPEEDS ARE FASTEST OBSERVED ONE-MINUTE VALUES WHEN DIRECTIONS ARE IN TENS OF DEGREES. THE / WITH THE DIRECTION INDICATES PEAK GUST SPEED.
ANY ERRORS DETECTED WILL BE CORRECTED AND CHANGES IN SUMMARY DATA WILL BE ANNOTATED IN THE ANNUAL SUMMARY.

DEC. SNOWFALL WAS GREATEST ON RECORD.

SUMMARY BY HOURS

Hour local time	Averages: Sky cover tenths	Station pressure in.	Temperature: Air °F	Wet bulb °F	Dew pt. °F	Relative humidity %	Wind speed m.p.h.	Resultant wind: Direction	Speed m.p.h.
00	7	29.24	22	21	18	79	11.8	24	4.0
03	8	29.24	21	19	15	79	11.9	23	3.3
06	8	29.24	20	19	14	78	11.4	22	4.0
09	7	29.27	21	20	16	79	11.8	23	5.2
12	7	29.24	26	23	17	71	13.5	23	5.8
15	8	29.23	27	24	18	70	13.3	24	5.4
18	7	29.26	25	23	17	75	11.5	24	3.8
21	7	29.28	23	22	17	80	11.5	23	3.7

HOURLY PRECIPITATION (WATER EQUIVALENT IN INCHES)

Date	A.M. 1	2	3	4	5	6	7	8	9	10	11	12	P.M. 1	2	3	4	5	6	7	8	9	10	11	12	Date
1	.09	.02	.09	.01	.01	.01	.01	T	T						T	T									1
2																			.01	.08	.10	.09	.09	.10	2
3	.08	.06																							3
4																									4
5			T	.01	.01	.02	.01	.04	T	T	.03	.01	T	.02	.09	.04	.04	.09	.04	.03	.01	.01	.01	.02	5
6	T																								6
7																T	T								7
8									T	T	.03	.01	.05	.05	.08	.04	.02	.01	.01	T	T	.01	T		8
9																					T	T			9
10																									10
11																									11
12																							T	T	12
13				T	T	T	T	T	T	T	T	T	T	T	T	T	T				T	T			13
14					T	T	T	T																	14
15																									15
16																									16
17				T	T	T		T	T										T	T					17
18		T	T																						18
19																			T	T	.07	.09	.09	.13	19
20	.03	.02	.02	.02	.01	.02	.01	.03	.02	.01	.01	T	T	T	T	.01	T	T				T	T	T	20
21		T	T	T	T	.01	.01	T	.01	.01	T						T	T							21
22																									22
23																									23
24																									24
25		T	T						T	T	T														25
26																									26
27																									27
28						T	T	T																	28
29																									29
30																									30
31						T		T	T	T	T	T	T	T					T	.08	.09	.08	.01	T	31

SUBSCRIPTION PRICE: $2.55 PER YEAR, FOREIGN MAILING $1.85 EXTRA. SINGLE COPY: 20 CENTS FOR MONTHLY ISSUE, 20 CENTS FOR ANNUAL SUMMARY. OTHER DATA IN RECORDS ON FILE CAN BE FURNISHED AT COST VIA MICROFILM, MICROFICHE, OR PAPER COPIES OF ORIGINAL RECORDS. MAKE CHECKS PAYABLE TO DEPARTMENT OF COMMERCE, NOAA. SEND PAYMENTS, ORDERS, AND INQUIRIES TO NATIONAL CLIMATIC CENTER, FEDERAL BUILDING, ASHEVILLE, NORTH CAROLINA 28801.

I CERTIFY THAT THIS IS AN OFFICIAL PUBLICATION OF THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, AND IS COMPILED FROM RECORDS ON FILE AT THE NATIONAL CLIMATIC CENTER, ASHEVILLE, NORTH CAROLINA 28801.

noaa NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION / ENVIRONMENTAL DATA SERVICE

Daniel B. Mitchell
DIRECTOR, NATIONAL CLIMATIC CENTER

USCOMM--NOAA--ASHEVILLE 01/19/78 400

OBSERVATIONS AT 3-HOUR INTERVALS

DAY 01

HOUR	SKY COVER (TENTHS)	CEILING (HUNDREDS OF FT.)	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE DRY BULB °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	10	2	0	12	SF	32	32	31	96	31	13
03	10	5	4		SF	30	28	28	92	28	11
06	10	4	1		SF	30	28	28	92	23	8
09	7	10	5		F	33	32	31	92	25	13
12	8	90	10			37	34	30	76	18	13
15	10	21	20		SW	36	32	27	73	24	18
18	10	30	12			34	30	24	67	23	18
21	10	25	12			33	30	24	70	25	14

DAY 02

HOUR	SKY COVER (TENTHS)	CEILING (HUNDREDS OF FT.)	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE DRY BULB °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	10	30	15			33	30	25	72	21	8
03	8	50	15			31	28	25	78	22	6
06	9	32	15			30	28	24	78	20	8
09	7	UNL	7			30	28	26	85	20	8
12	0	UNL	15			38	32	24	62	23	12
15	10	UNL	20			38	31	22	57	24	8
18	10	120	12			33	30	26	75	13	6
21	10	8	0	8	SF	31	31	30	96	00	0

DAY 03

HOUR	SKY COVER (TENTHS)	CEILING (HUNDREDS OF FT.)	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE DRY BULB °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	10	4	0	12	SF	30	30	28	96	01	8
03	10	40	5		F	25	24	22	88	34	7
06	5	UNL	10			18	18	14	81	34	8
09	8	180	10			15	14	10	80	34	4
12	10	80	12			18	17	11	71	24	4
15	10	80	10			21	19	13	71	24	3
18	10	80	12			20	19	14	77	30	5
21	3	UNL	12			17	16	13	84	34	6

DAY 04

HOUR	SKY COVER (TENTHS)	CEILING (HUNDREDS OF FT.)	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE DRY BULB °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	10	90	8			18	18	15	84	02	3
03	7	90	10			18	18	15	84	03	7
06	8	99	10			18	18	14	81	00	7
09	8	UNL	7			20	18	13	74	07	8
12	10	70	7			26	23	14	60	08	8
15	10	70	8			27	24	16	63	08	8
18	10	39	8			28	24	20	70	09	7
21	10	40	8			27	26	22	81	08	14

DAY 05

HOUR	SKY COVER (TENTHS)	CEILING (HUNDREDS OF FT.)	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE DRY BULB °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	10	40	10			28	27	23	82	09	16
03	10	19	9		ZRS	28	27	23	78	08	14
06	10	15	2		SF	27	26	24	88	01	14
09	10	15	3		SF	28	28	26	88	35	10
12	10	5	1		SF	32	31	29	88	02	12
15	10	4	0	12	SF	30	29	28	92	36	16
18	10	8	0	12	SF	28	28	26	92	31	13
21	10	8	2	8	SF	29	24	21	69	31	14

DAY 06

HOUR	SKY COVER (TENTHS)	CEILING (HUNDREDS OF FT.)	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE DRY BULB °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	10	13	7		S	14	13	10	84	30	17
03	3	UNL	8			04	03	-02	76	30	23
06	0	UNL	9			-03	-04	-15	56	30	18
09	0	UNL	10			-05	-09	-15	61	28	21
12	4	UNL	10			-02	-03	-13	56	28	22
15	4	UNL	8			00	00	-11	58	28	20
18	0	UNL	15			-01	-02	-10	65	28	10
21	0	UNL	15			-01	-01	-08	68	28	6

DAY 07

HOUR	SKY COVER (TENTHS)	CEILING (HUNDREDS OF FT.)	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE DRY BULB °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	0	UNL	15			-02	-02	-09	72	28	10
03	3	UNL	15			-07	-07	-13	75	00	0
06	8	UNL	15			-05	-05	-12	71	33	4
09	7	UNL	12			-02	-02	-08	72	00	0
12	2	UNL	12			07	08	-02	66	19	4
15	8	UNL	12			08	07	-01	66	18	11
18	10	60	15			12	10	03	67	11	8
21	8	UNL	15			13	11	08	84	14	10

DAY 08

HOUR	SKY COVER (TENTHS)	CEILING (HUNDREDS OF FT.)	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE DRY BULB °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	8	UNL	15			12	11	08	84	14	11
03	10	80	15			15	14	10	80	14	12
06	10	15	15			16	16	13	77	14	12
09	10	22	4		S	21	20	18	81	14	10
12	10	8	0	10	S	24	24	23	93	15	3
15	10	5	0	8	SF	29	29	23	82	32	7
18	10	11	4		SBS	31	20	17	84	30	17
21	8	20	5		SBS	14	13	10	84	28	16

DAY 09

HOUR	SKY COVER (TENTHS)	CEILING (HUNDREDS OF FT.)	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE DRY BULB °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	3	UNL	6		BS	08	05	00	76	27	18
03	0	UNL	7			-02	-03	-12	62	28	18
06	0	UNL	6			-09	-09	-19	61	26	17
09	2	UNL	5		BS	-02	-03	-12	62	28	18
12	10	UNL	2	8	BS	01	00	-09	62	27	18
15	10	UNL	2	8	BS	00	00	-09	65	27	20
18	0	UNL	10			-02	-03	-12	62	28	15
21	0	UNL	1	8	IC	-03	-03	-11	68	28	11

DAY 10

HOUR	SKY COVER (TENTHS)	CEILING (HUNDREDS OF FT.)	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE DRY BULB °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	0	UNL	12			-08	-08	-17	66	31	12
03	0	UNL	12			-08	-08	-18	61	31	8
06	8	180	12			-07	-07	-17	61	28	7
09	10	100	20			-06	-06	-16	61	29	6
12	7	180	20			-01	-02	-13	56	28	7
15	3	UNL	20			04	03	-08	57	18	5
18	0	UNL	20			01	00	-09	60	18	3
21	3	UNL	15			-09	-09	-12	71	32	3

DAY 11

HOUR	SKY COVER (TENTHS)	CEILING (HUNDREDS OF FT.)	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE DRY BULB °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	0	UNL	12			-01	-01	-07	75	00	0
03	0	UNL	12			-01	-01	-08	72	07	4
06	0	UNL	12			00	00	-07	73	10	6
09	8	100	12			09	04	-02	72	11	7
12	8	UNL	12			13	11	03	64	13	11
15	8	UNL	12			17	16	10	74	14	11
18	8	37	12			18	18	14	81	14	14
21	10	39	12			24	23	18	81	16	13

DAY 12

HOUR	SKY COVER (TENTHS)	CEILING (HUNDREDS OF FT.)	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE DRY BULB °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	10	39	12			30	27	20	66	18	15
03	10	40	12			32	29	22	67	18	12
06	10	30	12			34	30	22	62	18	15
09	10	39	15			38	32	24	62	18	14
12	10	30	20			38	33	26	62	18	14
15	10	25	20			37	33	27	67	18	14
18	10	18	15			35	33	28	75	16	9
21	10	18	15			37	34	30	76	17	11

DAY 13

HOUR	SKY COVER (TENTHS)	CEILING (HUNDREDS OF FT.)	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE DRY BULB °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	10	17	12			37	34	30	76	18	10
03	10	18	12			38	34	30	75	17	10
06	10	14	7		L	39	34	33	82	17	8
09	10	3	0	8	LF	35	35	34	96	16	7
12	10	10	3		LF	37	36	35	92	18	8
15	10	1	0	2	LF	38	38	38	100	19	4
18	10	0	0		F	39	39	39	100	20	3
21	10	1	0	2	LF	34	34	34	100	20	5

DAY 14

HOUR	SKY COVER (TENTHS)	CEILING (HUNDREDS OF FT.)	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE DRY BULB °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	10	2	1	8	F	33	33	32	96	34	8
03	10	5	2		F	31	30	28	92	34	10
06	10	2	0	8	LF	31	31	30	96	34	6
09	10	4	1	8	F	32	31	30	92	33	7
12	10	3	2	8	F	31	30	28	92	31	8
15	10	3	2	8	F	31	30	28	92	29	4
18	10	3	2	8	F	31	30	28	89	18	5
21	10	3	2		F	31	30	28	92	18	6

DAY 15

HOUR	SKY COVER (TENTHS)	CEILING (HUNDREDS OF FT.)	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE DRY BULB °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	10	0	0	1	F	30	30	30	100	17	13
03	10	2	0	1	F	30	30	29	96	18	11
06	10	2	0	2	F	30	30	29	96	17	10
09	10	2	0	8	F	31	31	30	96	17	12
12	10	120	3		F	36	35	33	89	18	13
15	10	250	6		H	38	37	35	88	15	11
18	10	250	6		H	40	38	37	89	14	13
21	10	3	4		FH	36	35	34	92	16	13

DAY 16

HOUR	SKY COVER (TENTHS)	CEILING (HUNDREDS OF FT.)	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE DRY BULB °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	2	UNL	6		FH	35	34	32	89	18	15
03	2	UNL	5		FH	36	35	33	89	15	15
06	3	UNL	5		FH	37	36	34	89	15	14
09	10	2	0	12	F	38	38	37	93	18	14
12	7	10	4		H	44	42	38	83	14	18
15	4	UNL	7			48	46	42	80	14	15
18	10	28	6		H	46	46	44	86	15	18
21	10	24	7			46	46	44	83	14	15

DAY 17

HOUR	SKY COVER (TENTHS)	CEILING (HUNDREDS OF FT.)	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE DRY BULB °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	10	28	8			50	47	46	83	13	15
03	9	180	10			53	48	48	77	15	20
06	10	90	15			53	47	42	66	15	18
09	8	40	15			47	43	38	66	18	16
12	8	48	15			50	43	35	57	18	18
15	10	40	20			47	42	35	63	18	15
18	10	48	15			46	41	34	63	18	15
21	8	20	15			38	37	34	82	16	10

DAY 18

HOUR	SKY COVER (TENTHS)	CEILING (HUNDREDS OF FT.)	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE DRY BULB °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	10	23	15			38	36	34	86	18	7
03	10	16	10			38	37	35	89	21	8
06	10	22	12			37	36	34	89	22	7
09	10	12	8			37	35	32	82	27	7
12	10	12	7			38	35	31	76	25	10
15	10	15	7			37	35	31	78	24	8
18	10	17	7			37	35	31	79	25	5
21	10	14	8			38	34	30	78	23	6

DAY 19

HOUR	SKY COVER (TENTHS)	CEILING (HUNDREDS OF FT.)	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE DRY BULB °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	7	200	8			33	31	28	82	24	3
03	8	UNL	12			28	28	27	96	06	4
06	8	UNL	3		F	28	28	28	92	03	5
09	5	UNL	3		F	32	31	28	86	07	8
12	8	80	10			41	37	31	68	08	10
15	10	70	10			41	38	33	73	05	12
18	10	13	8			38	38	32	78	36	10
21	10	8	2	8	SF	34	33	31	89	02	10

DAY 20

HOUR	SKY COVER (TENTHS)	CEILING (HUNDREDS OF FT.)	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE DRY BULB °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	10	3	0	12	S	32	31	30	92	30	8
03	10	6	1	8	S	30	28	27	88	30	18
06	10	8	6		S	24	23	18	81	28	17
09	10	12	1		SBS	21	20	17	84	27	14
12	10	12	2	8	SBS	18	18	14	81	28	20
15	10	15	2		SBS	17	18	11	77	28	18
18	10	14	8		BS	18	15	11	81	25	14
21	10	UNL	8		BS	18	15	11	81	24	13

DAY 21

HOUR	SKY COVER (TENTHS)	CEILING (HUNDREDS OF FT.)	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE DRY BULB °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	10	12	8		BS	17	16	12	81	25	13
03	10	13	8		S	17	18	12	81	24	11
06	10	12	4		S	18	17	14	84	28	13
09	10	17	2	8	S	19	18	14	81	28	14
12	10	16	4		S	20	18	15	81	27	15
15	10	22	5		S	20	18	15	81	28	14
18	10	16	10			18	18	13	77	28	11
21	10	12	8			21	20	16	81	28	15

DAY 22

HOUR	SKY COVER (TENTHS)	CEILING (HUNDREDS OF FT.)	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE DRY BULB °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	1	UNL	10			18	15	10	77	28	10
03	0	UNL	12			13	12	08	80	25	8
06	0	UNL	12			10	08	05	80	23	7
09	0	UNL	12			13	12	08	80	18	10
12	10	140	15			24	22	18	71	18	14
15	8	UNL	15			32	28	20	61	18	15
18	10	220	15			31	27	20	64	17	18
21	10	220	15			32	28	21	64	17	17

DAY 23

HOUR	SKY COVER (TENTHS)	CEILING (HUNDREDS OF FT.)	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE DRY BULB °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	8	110	15			33	28	21	61	17	16
03	2	UNL	15			32	29	18	56	18	15
06	2	UNL	15			30	28	18	61	22	8
09	0	UNL	15			31	28	21	66	20	14
12	0	UNL	15			32	28	22	67	28	10
15	1	UNL	15			32	28	21	64	27	7
18	3	UNL	15			28	28	20	73	17	4
21	0	UNL	15			26	24	20	78	18	6

DAY 24

HOUR	SKY COVER (TENTHS)	CEILING (HUNDREDS OF FT.)	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE DRY BULB °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	0	UNL	15			24	23	20	85	16	4
03	9	UNL	12			28	28	25	85	16	6
06	10	300	12			34	31	27	76	16	10
09	10	130	7			35	33	31	85	15	12
12	10	3	2	8	F	38	34	32	85	18	14
15	0	UNL	8			40	38	30	68	27	18
18	5	UNL	15			25	23	18	68	31	16
21	0	UNL	15			20	17	08	62	30	15

DAY 25

HOUR	SKY COVER (TENTHS)	CEILING (HUNDREDS OF FT.)	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE DRY BULB °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	0	UNL	15			15	13	05	64	27	18
03	2	UNL	12			13	11	01	58	28	17
06	4	UNL	12			12	10	03	67	27	14
09	10	23	0	12	S	12	11	08	77	28	13
12	8	24	7			08	07	-05	93	28	20
15	4	UNL	12			07	05	-08	90	28	18
18	0	UNL	20			04	02	-10	93	28	15
21	0	UNL	20			04	03	-08	97	28	13

DAY 26

HOUR	SKY COVER (TENTHS)	CEILING (HUNDREDS OF FT.)	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE DRY BULB °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	8	28	20			07	05	-04	60	25	8
03	0	UNL	15			04	03	-04	68	23	5
06	0	UNL	15			04	03	-04	68	21	5
09	0	UNL	15			08	08	01	70	23	8
12	7	210	15			15	12	-01	48	28	10
15	8	UNL	15			15	12	02	56	28	13
18	0	UNL	20			11	08	02	67	28	10
21	0	UNL	20			08	08	01	70	28	14

DAY 27

HOUR	SKY COVER (TENTHS)	CEILING (HUNDREDS OF FT.)	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE DRY BULB °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	2	UNL	20			08	04	-05	60	31	17
03	0	UNL	15			03	02	-07	63	31	10
06	0	UNL	15			01	00	-08	65	30	10
09	0	UNL	15			02	01	-08	58	28	11
12	0	UNL	15			07	05	-08	55	28	11
15	0	UNL	15			12	08	-04	48	28	9
18	2	UNL	15			08	07	-05	53	24	5
21	1	UNL	15			06	05	-04	63	20	4

DAY 28

HOUR	SKY COVER (TENTHS)	CEILING (HUNDREDS OF FT.)	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE DRY BULB °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	7	UNL	15			07	08	-03	63	20	8
03	10	200	12			10	08	00	64	18	7
06	10	40	7		S	15	13	04	61	15	10
09	10	70	10			20	18	15	81	21	13
12	3	UNL	12			28	25	17	61	25	11
15	5	UNL	15			31	27	18	58	28	12
18	2	UNL	15			25	22	15	66	28	9
21	10	100	15			24	22	18	71	18	6

DAY 29

HOUR	SKY COVER (TENTHS)	CEILING (HUNDREDS OF FT.)	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE DRY BULB °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	10	90	15			25	23	18	75	18	5
03	10	80	12			25	23	18	78	18	6
06	0	UNL	12			22	21	17	81	18	8
09	1	UNL	7			24	22	17	75	18	8
12	5	UNL	10			35	30	22	58	15	11
15	8	UNL	10			41	35	28	59	20	10
18	3	UNL	10			35	32	28	76	24	5
21	3	UNL	7			26	26	24	92	30	3

DAY 30

HOUR	SKY COVER (TENTHS)	CEILING (HUNDREDS OF FT.)	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE DRY BULB °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	3	UNL	3		F	23	23	22	96	00	0
03	1	UNL	0	8	F	18	18	18	100	00	0
06	0	UNL	4		F	18	18	18	100	05	4
09	0	UNL	2	8	F	22	22	20	92	01	5
12	0	UNL	2	8	H	27	26	22	81	36	7
15	2	UNL	5		H	30	28	23	75	36	8
18	4	UNL	2	8	FH	24	23	20	85	02	5
21	10	2	1	8	F	24	24	22	92	07	6

DAY 31

HOUR	SKY COVER (TENTHS)	CEILING (HUNDREDS OF FT.)	VISIBILITY WHOLE MILES	VISIBILITY 16THS MILE	WEATHER	TEMPERATURE DRY BULB °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	10	2	1		F	29	28	22	90	03	4
03	10	17	1	8	F	25	24	22	88	08	7
06	10	12	4		F	28	27	25	88	07	8
09	10	4	1	8	ZLF	28	28	25	89	08	8
12	10	12	1	8	F	31	30	27	85	07	7
15	10	11	2		F	34	32	28	82	10	10
18	10	18	2	8	H	33	31	28	82	08	11
21	10	4	0	12	SF	32	31	28	89	11	10

STATION: PEORIA ILL

YEAR & MONTH: 77 12

NOTES

CEILING
UNL INDICATES UNLIMITED

WEATHER

- * TORNADO
- T THUNDERSTORM
- Q SQUALL
- R RAIN
- RW RAIN SHOWERS
- ZR FREEZING RAIN
- L DRIZZLE
- ZL FREEZING DRIZZLE
- S SNOW
- SP SNOW PELLETS
- IC ICE CRYSTALS
- SW SNOW SHOWERS
- SG SNOW GRAINS
- IP ICE PELLETS
- A HAIL
- F FOG
- IF ICE FOG
- GF GROUND FOG
- BD BLOWING DUST
- BN BLOWING SAND
- BS BLOWING SNOW
- BY BLOWING SPRAY
- K SMOKE
- H HAZE
- D DUST

WIND

DIRECTIONS ARE THOSE FROM WHICH THE WIND BLOWS. INDICATED IN TENS OF DEGREES FROM TRUE NORTH: I.E., 09 FOR EAST, 18 FOR SOUTH, 27 FOR WEST. ENTRY OF 00 IN THE DIRECTION COLUMN INDICATES CALM.

SPEED IS EXPRESSED IN KNOTS; MULTIPLY BY 1.15 TO CONVERT TO MILES PER HOUR.

U.S. DEPARTMENT OF COMMERCE
NATIONAL CLIMATIC CENTER
FEDERAL BUILDING
ASHEVILLE, N.C. 28801

PEORIA, ILLINOIS
NATIONAL WEATHER SERVICE OFC
GREATER PEORIA AIRPORT

Local Climatological Data

MONTHLY SUMMARY

JANUARY 1978 PEORIA, ILLINOIS

LATITUDE 40° 40' N LONGITUDE 89° 41' W ELEVATION (GROUND) 652 FT. STANDARD TIME USED: CENTRAL WBAN #14842

Date	Temperature °F Maximum	Minimum	Average	Departure from normal	Average dew point	Degree days base 65° Heating (season begins with July)	Cooling (season begins with Jan.)	Weather types on dates of occurrence (1 Fog, 2 Heavy fog, 3 Thunderstorm, 4 Ice pellets, 5 Hail, 6 Glaze, 7 Duststorm, 8 Smoke, haze, 9 Blowing snow)	Snow, ice pellets or ice on ground at 06AM In.	Precipitation Water equivalent In.	Snow, ice pellets In.	Avg. station pressure In. Elev. 662 feet m.s.l.	Wind Resultant dir.	Resultant speed M.P.H.	Average speed	Fastest mile Speed M.P.H.	Direction	Sunshine Minutes	Percent of possible	Sky cover tenths Sunrise to sunset	Midnight to midnight	Date
1	2	3	4	5	6	7A	7B	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	32	-2	15	-8	11	50	0	1 8 9	2	.09	.3	29.38	28	15.4	16.8	24	W	170	30	7	8	1
2	17	-4	7	-17	-2	58	0		2	0	0	29.40	25	10.8	11.9	17	W	558	100	0	0	2
3	21	-3	9	-15	4	56	0	8	2	T	T	29.59	19	5.4	8.1	10	S	561	100	1	0	3
4	37	16	27	3	20	38	0		2	T	0	29.49	18	8.2	8.8	10	SW	344	61	8	8	4
5	38*	29	34	10	29	31	0	1 8	2	T	0	29.38	12	3.6	5.3	7	S	98	18	9	7	5
6	39	28	31	7	28	34	0	2	1	T	0	29.30	13	5.8	7.1	7	S	32	6	10	10	6
7	38	33	36*	12	34	29	0	2	T	T	0	29.18	11	2.7	6.6	16	NW	0	0	10	10	7
8	33	-1	16	-8	4	49	0	1 8 9	T	T	T	29.38	31	29.0	29.2	31	NW	354	63	6	6	8
9	2	-6	-2*	-26	-16	67	0		T	T	T	29.97	29	21.0	21.1	28	NW	495	87	3	2	9
10	9	-8*	1	-23	-16	64	0		T	T	0	29.79	29	14.8	15.1	16	NW	569	100	0	0	10
11	17	0	9	-14	-8	56	0		T	0	0	29.79	20	6.8	7.6	12	W	422	74	7	7	11
12	20	15	18	-5	7	47	0		T	.11	1.1	29.52	09	5.1	6.3	9	SE	95	17	10	10	12
13	22	13	18	-5	11	47	0	8	2	.04	.6	29.38	34	8.5	8.9	11	N	268	47	10	10	13
14	23	4	14	-8	10	51	0		3	.05	.8	29.42	34	13.8	14.5	17	N	470	82	8	6	14
15	18	-6	6	-17	-4	59	0		2	0	0	29.40	28	4.9	5.8	9	W	575	100	0	2	15
16	15	5	10	-13	4	55	0	8	2	.12	.8	29.52	35	8.2	9.8	13	N	366	63	10	10	16
17	24	5	15	-8	4	50	0	8	2	0	0	29.50	03	11.8	12.2	20	NE	527	91	2	3	17
18	25	2	14	-9	6	51	0	8	2	0	0	29.83	35	5.9	6.3	8	N	325	56	8	7	18
19	24	17	21	-3	13	44	0	8	2	T	T	29.83	01	11.1	11.5	19	NE	82	14	10	10	19
20	22	8	15	-8	12	50	0	8	2	.04	.4	29.47	34	12.6	13.5	19	N	147	25	9	8	20
21	16	-4	6	-18	-2	59	0	8	2	0	0	29.60	28	5.8	6.5	9	W	585	100	0	0	21
22	22	-4	9	-15	1	56	0	1 8	2	0	0	29.87	18	7.6	7.8	11	S	80	14	8	5	22
23	27	8	18	-6	10	47	0	1 8	2	0	0	29.57	15	10.3	10.6	12	S	506	86	4	4	23
24	33	22	28	4	22	37	0	1 6 8	2	.10	1.0	29.24	26	4.3	7.1	8	NW	1	0	10	10	24
25	20	-2	13	-11	11	52	0	8 9	2	.01	.1	29.82	30	11.7	12.2	27	NW	77	13	10	10	25
26	12	-2	5	-18	-2	60	0	9	2	.08	.8	29.89	27	27.5	27.6	31	W	46	8	10	10	26
27	12	-2	5	-18	-7	60	0		2	T	T	29.35	27	20.8	21.0	26	W	514	86	2	3	27
28	15	-2	7	-17	-5	58	0		2	0	0	29.52	28	18.1	16.3	18	W	540	90	5	2	28
29	11	-3	4	-20	-8	61	0		2	0	0	29.67	28	11.8	12.2	10	W	601	100	0	0	29
30	16	-6	5	-20	-1	60	0		2	.09	1.0	29.63	24	5.5	5.9	6	W	189	28	10	7	30
31	15	-3	6	-19	-3	59	0		2	0	0	29.88	28	7.2	7.5	9	NW	503	100	1	2	31

Sum	Sum				Total	Total		Total	Total	For the month:						Total	%	Sum	Sum
879	148				1595	0	Number of days	.88	7.0	29.47	29	8.4	11.6	31	W	10182	For	189	176
Avg.	Avg.	Avg.	Dep.	Avg.	Dep.	Dep.	Precipitation	Dep.						Date: 26+		Possible	Month	Avg.	Avg.
21.8	4.7	13.3	-10.5	5	318	0	≥ .01 inch 10	-1.13								17942	57	6.1	5.7

Number of days				Season to date						
				Total	Total	Snow, ice pellets ≥ 1.0 inch	2	Greatest in 24 hours and dates		Greatest depth on ground of snow, ice pellets or ice and date
Maximum temp.		Minimum temp.		4093	0	Thunderstorms	0	Precipitation	Snow, ice pellets	
≥ 90°	≤ 32°	≤ 32°	≤ 0°	Dep.	Dep.	Heavy fog	2	.13 12-13	1.5 12-13	3 31+
0	25	30	17	511	0	Clear 10	Partly cloudy 5	Cloudy 16		

* EXTREME FOR THE MONTH - LAST OCCURRENCE IF MORE THAN ONE.
T TRACE AMOUNT
+ ALSO ON AN EARLIER DATE, OR DATES.
HEAVY FOG: - VISIBILITY 1/4 MILE OR LESS.
FIGURES FOR WIND DIRECTIONS ARE TENS OF DEGREES CLOCKWISE FROM TRUE NORTH. 00 - CALM.
DATA IN COLS. 6 AND 12-15 ARE BASED ON 7 OR MORE OBSERVATIONS PER DAY AT 3-HOUR INTERVALS.
FASTEST MILE WIND SPEEDS ARE FASTEST OBSERVED ONE-MINUTE VALUES WHEN DIRECTIONS ARE IN TENS OF DEGREES. THE / WITH THE DIRECTION INDICATES PEAK GUST SPEED.
ANY ERRORS DETECTED WILL BE CORRECTED AND CHANGES IN SUMMARY DATA WILL BE ANNOTATED IN THE ANNUAL SUMMARY.

SUMMARY BY HOURS

Hour local time	Averages: Sky cover tenths	Station pressure In.	Temperature Air °F	Wet bulb °F	Dew pt. °F	Relative humidity %	Wind speed M.P.H.	Resultant wind Direction	Speed M.P.H.
00	5	29.46	12	11	5	72	10.5	29	5.6
03	5	29.46	11	10	3	71	10.6	29	6.0
06	5	29.49	10	9	2	70	9.8	29	5.4
09	6	29.46	11	10	4	71	11.5	30	6.0
12	6	29.48	17	15	7	65	14.4	30	7.6
15	6	29.45	19	17	8	64	13.6	29	7.5
18	6	29.48	18	14	7	68	11.3	29	6.3
21	5	29.49	13	12	5	70	11.2	29	5.6

HOURLY PRECIPITATION (WATER EQUIVALENT IN INCHES)

Date	A.M. hour ending at 1	2	3	4	5	6	7	8	9	10	11	12	P.M. hour ending at 1	2	3	4	5	6	7	8	9	10	11	12	Date
1	.03	.02							T	T	T		T	T											1
2																									2
3									T																3
4																									4
5												T													5
6																	T	T	T	T	T	T	T	T	6
7	T	T			T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	T	7
8						T	T	T		T	T	T	T	T	T	T									8
9								T	T	T	T														9
10																									10
11																									11
12								T	.01	.02	.01	T	T	T	.01	.01	.01	.01	T	.01	T	T	.01	.01	12
13	T	T	.01	.01	T	T	T	T	T	T	T	T	T	T	T	T	.01	T	T	T	T	T	.01	T	13
14	T	T	.01	.02	.01	.01	T	T	T																14
15																									15
16		T	T	T	.01	.02	.03	.02	.02	.01	.01	T	T	T	T										16
17																									17
18																									18
19											T	T	T	T	T	T	T					T	T	T	19
20	T	T	.01	.01	T	T	T	T	T	.01	T	T	T	.01	T	T	T	T		T	T	T			20
21																									21
22																									22
23																									23
24			.02	.01	.01	T	.02	.01	.01	.01	.01	T	T	T											24
25																		T	T	T	T	T	T	.01	25
26	T	T	.01	.02	.02	.01	.01	.01	T	T	T	T													26
27																						T	T	T	27
28																									28
29																									29
30														T	.01	.02	.03	.01	T	T	.01	.01	T	T	30
31																									31

I CERTIFY THAT THIS IS AN OFFICIAL PUBLICATION OF THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, AND IS COMPILED FROM RECORDS ON FILE AT THE NATIONAL CLIMATIC CENTER, ASHEVILLE, NORTH CAROLINA 28801.

noaa NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION / ENVIRONMENTAL DATA SERVICE

Daniel B. Mitchell
DIRECTOR, NATIONAL CLIMATIC CENTER

USCOMM--NOAA--ASHEVILLE 01/23/78 800

OBSERVATIONS AT 3-HOUR INTERVALS

Columns: HOUR · SKY COVER (TENTHS) · CEILING (HUNDREDS OF FT.) · VISIBILITY: WHOLE MILES · 16THS MILE · WEATHER · TEMPERATURE: AIR °F · WET BULB °F · DEW PT. °F · REL. HUM. % · WIND: DIR · SPEED KNOTS

DAY 01

HOUR	SKY COVER	CEILING	VIS. WHOLE MILES	VIS. 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	10	3	0	12	SF	32	31	30	92	19	9
03	10	3	1		F	32	31	30	92	20	12
06	10	7	5		H	23	22	18	85	20	16
09	10	12	7		S	17	16	13	84	20	18
12	8	80	5		BS	16	15	10	77	20	18
15	3	UNL	5		BS	08	08	03	78	20	17
18	0	UNL	6		BS	04	03	-08	57	20	17
21	0	UNL	10			00	00	-10	62	20	14

DAY 02

HOUR	SKY COVER	CEILING	VIS. WHOLE MILES	VIS. 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	0	UNL	15			-02	-02	-11	66	26	7
03	0	UNL	15			-02	-02	-11	66	24	8
06	0	UNL	15			-01	-01	-08	68	20	8
09	0	UNL	15			07	06	-02	66	23	10
12	0	UNL	20			14	12	03	61	26	15
15	1	UNL	20			18	14	05	62	26	14
18	0	UNL	15			11	10	05	77	26	8
21	0	UNL	15			10	08	03	73	27	12

DAY 03

HOUR	SKY COVER	CEILING	VIS. WHOLE MILES	VIS. 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	0	UNL	15			08	07	02	76	26	10
03	0	UNL	15			04	03	-02	76	24	5
06	0	UNL	15			-01	-01	-08	72	23	3
09	0	UNL	7			00	00	-05	79	18	5
12	1	UNL	10			14	13	08	77	15	6
15	0	UNL	12			21	18	12	68	16	8
18	0	UNL	12			17	16	11	77	15	7
21	0	UNL	12			20	18	14	77	16	8

DAY 04

HOUR	SKY COVER	CEILING	VIS. WHOLE MILES	VIS. 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	0	UNL	15			18	17	13	81	17	6
03	10	250	15			22	21	16	76	17	6
06	7	250	15			25	23	17	72	18	10
09	7	UNL	15			28	26	18	63	18	10
12	10	UNL	12			35	30	21	57	22	11
15	10	250	12			36	32	24	62	18	8
18	10	220	12			34	31	25	70	15	6
21	10	220	12			33	30	25	72	16	6

DAY 05

HOUR	SKY COVER	CEILING	VIS. WHOLE MILES	VIS. 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	10	70	12			32	30	25	75	18	6
03	10	65	12			32	30	25	75	15	6
06	10	50	10			32	30	25	75	14	4
09	10	40	8			33	30	25	72	00	0
12	10	50	8			36	32	26	67	06	5
15	10	34	8			38	34	27	65	17	5
18	7	120	8			34	31	26	73	06	4
21	2	UNL	8			28	28	24	82	04	5

DAY 06

HOUR	SKY COVER	CEILING	VIS. WHOLE MILES	VIS. 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	2	UNL	4		F	28	27	25	88	08	6
03	10	2	0	3	F	28	26	24	92	10	6
06	10	3	3		F	28	28	26	88	07	5
09	10	2	1		F	31	30	28	88	10	5
12	10	4	3		F	35	33	30	82	15	6
15	10	1	0	3	F	33	32	31	92	15	6
18	10	1	0	3	LF	34	33	32	92	13	5
21	10	1	0	2	LF	34	34	34	100	13	6

DAY 07

HOUR	SKY COVER	CEILING	VIS. WHOLE MILES	VIS. 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	10	1	0	2	LF	35	35	35	100	17	6
03	10	1	0	2	F	35	34	32	88	15	10
06	10	1	0	2	LF	35	34	33	92	13	6
09	10	2	0	6	LF	37	36	35	92	10	6
12	10	1	0	6	LF	37	36	35	92	05	7
15	10	1	0	6	LF	37	36	35	92	03	4
18	10	1	0	12	LF	35	35	35	100	34	6
21	10	1	2	6	LF	34	34	33	96	30	6

DAY 08

HOUR	SKY COVER	CEILING	VIS. WHOLE MILES	VIS. 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	10	3	2	6	F	33	32	31	92	31	16
03	10	6	2	6	F	28	27	24	85	30	20
06	10	12	5		SW	15	14	08	77	30	22
09	6	100	12			08	06	02	73	31	25
12	7	18	5		SW	07	06	-03	63	30	27
15	5	UNL	3		SW	03	02	-10	54	30	22
18	6	23	5		BS	00	00	-12	56	31	24
21	3	UNL	7			01	00	-12	54	32	18

DAY 09

HOUR	SKY COVER	CEILING	VIS. WHOLE MILES	VIS. 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	1	UNL	7			00	00	-13	54	30	18
03	0	UNL	10			-02	-03	-14	56	28	18
06	0	UNL	10			-04	-05	-16	56	28	17
09	6	UNL	6		SW	-05	-06	-17	55	30	22
12	6	UNL	10			-01	-02	-16	40	30	22
15	0	UNL	15			02	00	-17	40	30	18
18	0	UNL	20			-02	-03	-16	51	28	16
21	1	UNL	20			-03	-04	-17	50	28	16

DAY 10

HOUR	SKY COVER	CEILING	VIS. WHOLE MILES	VIS. 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	2	UNL	20			-05	-06	-10	80	30	14
03	3	UNL	20			-05	-06	-10	83	28	14
06	0	UNL	20			-07	-07	-10	86	28	14
09	0	UNL	20			-05	-06	-10	80	30	14
12	0	UNL	20			03	01	-14	44	27	15
15	0	UNL	20			06	05	-13	37	28	14
18	0	UNL	20			05	03	-12	46	27	8
21	0	UNL	15			03	01	-11	51	28	11

DAY 11

HOUR	SKY COVER	CEILING	VIS. WHOLE MILES	VIS. 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	0	UNL	12			01	00	-11	56	31	10
03	3	UNL	15			01	00	-10	58	24	5
06	6	200	15			03	02	-08	57	27	6
09	2	UNL	15			05	03	-08	54	28	6
12	10	120	15			13	08	-06	38	28	11
15	6	120	15			17	13	-06	32	28	6
18	10	UNL	15			13	10	-06	42	25	4
21	6	70	12			14	11	-02	48	20	3

DAY 12

HOUR	SKY COVER	CEILING	VIS. WHOLE MILES	VIS. 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	10	60	12			15	12	-03	44	18	4
03	10	70	10			16	12	-03	43	18	3
06	10	50	10			17	14	00	47	08	3
09	10	20	1		S	16	15	10	77	10	6
12	10	11	5		S	18	17	12	77	08	6
15	10	11	1	6	S	18	16	13	77	08	6
18	10	11	3		S	18	17	12	77	08	4
21	10	40	4		S	17	16	12	81	09	5

DAY 13

HOUR	SKY COVER	CEILING	VIS. WHOLE MILES	VIS. 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	10	70	2	6	S	16	15	12	84	02	5
03	10	55	3		S	15	14	10	80	02	5
06	10	70	5		S	14	13	08	80	34	5
09	10	60	5		SW	15	14	08	77	32	7
12	10	60	5		SW	17	15	08	71	34	6
15	10	60	3		SW	18	17	12	74	33	11
18	10	50	2	6	SW	18	17	13	81	33	10
21	10	6	3		S	20	18	14	77	33	10

DAY 14

HOUR	SKY COVER	CEILING	VIS. WHOLE MILES	VIS. 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	10	35	5		S	22	21	18	78	35	12
03	10	6	2		S	22	21	17	81	36	16
06	10	60	5		S	18	17	12	74	35	14
09	6	UNL	6			17	16	10	74	36	17
12	6	UNL	10			20	17	08	62	34	13
15	6	UNL	15			20	18	10	65	33	12
18	1	UNL	15			14	12	05	67	31	6
21	0	UNL	15			08	08	01	70	32	6

DAY 15

HOUR	SKY COVER	CEILING	VIS. WHOLE MILES	VIS. 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	0	UNL	15			04	03	-04	68	28	6
03	0	UNL	15			01	00	-07	68	28	6
06	0	UNL	15			-02	-02	-10	68	00	0
09	0	UNL	10			-01	-01	-08	68	00	0
12	0	UNL	10			13	11	01	58	28	6
15	0	UNL	15			15	12	-02	47	28	6
18	0	UNL	15			11	08	-01	58	23	5
21	7	250	15			07	06	-01	68	18	5

DAY 16

HOUR	SKY COVER	CEILING	VIS. WHOLE MILES	VIS. 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	10	20	10			11	10	04	73	22	5
03	10	15	1	6	S	12	11	06	77	31	6
06	10	10	1	6	S	11	10	06	80	01	5
09	10	7	1		S	11	10	06	80	36	5
12	10	12	3		S	14	12	06	70	34	6
15	10	UNL	5		H	13	12	05	70	01	10
18	10	UNL	6		H	08	07	00	70	01	12
21	10	250	7			06	05	-04	63	36	11

DAY 17

HOUR	SKY COVER	CEILING	VIS. WHOLE MILES	VIS. 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	10	UNL	6			05	04	-04	66	01	6
03	6	250	10			05	04	-03	68	36	7
06	6	UNL	10			07	06	00	73	01	6
09	1	UNL	6			13	11	03	64	03	10
12	0	UNL	6			22	18	10	60	04	20
15	3	UNL	15			24	21	12	60	03	14
18	0	UNL	15			18	17	08	63	04	7
21	1	UNL	15			15	14	08	74	01	7

DAY 18

HOUR	SKY COVER	CEILING	VIS. WHOLE MILES	VIS. 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	0	UNL	15			09	08	04	80	34	5
03	0	UNL	15			03	02	-06	66	31	6
06	0	UNL	15			04	03	-04	68	33	5
09	6	UNL	6			11	10	03	70	02	6
12	10	100	6		H	21	18	10	62	01	4
15	10	120	6		H	24	21	13	63	34	7
18	10	120	10			23	21	14	68	36	5
21	10	60	12			21	18	13	71	36	6

DAY 19

HOUR	SKY COVER	CEILING	VIS. WHOLE MILES	VIS. 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	10	65	10			18	17	12	74	36	7
03	10	40	12			18	17	11	71	01	6
06	10	20	12			18	17	11	71	36	7
09	10	30	10			18	17	11	71	36	6
12	10	60	10		SW	23	21	14	68	04	14
15	10	30	5		S	24	22	16	71	01	12
18	10	12	6			22	20	15	74	36	12
21	10	20	12			18	17	12	74	36	11

DAY 20

HOUR	SKY COVER	CEILING	VIS. WHOLE MILES	VIS. 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	10	60	10		S	18	17	12	74	01	10
03	10	50	5		S	19	18	14	81	36	10
06	10	40	6		S	18	16	13	77	35	12
09	10	40	4		S	18	17	12	77	35	14
12	6	12	6		S	21	18	13	71	34	14
15	10	12	2	6	S	21	18	14	74	32	13
18	5	UNL	10			18	17	11	74	31	11
21	6	30	6		S	13	12	08	80	31	10

DAY 21

HOUR	SKY COVER	CEILING	VIS. WHOLE MILES	VIS. 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	0	UNL	10			08	07	01	73	30	6
03	0	UNL	10			06	05	-03	66	31	6
06	0	UNL	10			01	00	-08	65	27	5
09	0	UNL	6			01	00	-08	62	26	5
12	0	UNL	7			11	08	00	61	27	7
15	0	UNL	10			15	13	05	64	27	7
18	0	UNL	10			10	08	00	64	22	5
21	0	UNL	10			04	03	-04	68	00	0

DAY 22

HOUR	SKY COVER	CEILING	VIS. WHOLE MILES	VIS. 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	0	UNL	7			-04	-04	-13	65	18	4
03	4	UNL	6			01	00	-08	65	18	3
06	1	UNL	5		KH	-02	-02	-08	72	00	0
09	6	60	5		FH	06	05	-01	73	18	4
12	10	60	10			18	16	08	65	17	12
15	10	45	12			22	18	11	62	15	12
18	6	UNL	12			18	17	10	68	18	6
21	0	UNL	12			16	14	07	67	18	10

DAY 23

HOUR	SKY COVER	CEILING	VIS. WHOLE MILES	VIS. 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	0	UNL	12			13	12	05	70	18	6
03	0	UNL	12			10	08	03	73	16	6
06	0	UNL	12			11	10	04	73	15	6
09	0	UNL	6			14	13	08	70	15	6
12	0	UNL	7			22	20	13	68	14	12
15	6	UNL	7			26	24	17	68	15	13
18	10	6	4		H	23	22	17	78	15	11
21	10	75	2		FH	22	21	17	81	20	7

DAY 24

HOUR	SKY COVER	CEILING	VIS. WHOLE MILES	VIS. 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	10	70	5		FH	22	21	18	78	17	5
03	10	20	2		SF	24	23	18	78	18	6
06	10	44	2		F	26	25	21	81	18	4
09	10	3	1		SF	26	26	25	96	23	6
12	10	6	2		SF	32	30	26	78	20	7
15	10	11	6		F	32	30	26	79	30	11
18	7	18	7			26	25	21	81	20	6
21	10	60	7			27	26	22	81	20	4

DAY 25

HOUR	SKY COVER	CEILING	VIS. WHOLE MILES	VIS. 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	10	70	3		H	26	25	21	81	25	4
03	10	70	3		H	22	21	18	78	32	6
06	10	UNL	5		H	18	17	12	77	33	5
09	10	75	4		H	16	15	11	81	33	3
12	10	80	10			25	22	14	63	28	6
15	10	80	12			27	24	18	68	28	14
18	10	30	6		S	11	10	03	70	30	22
21	10	60	7			01	00	-11	58	28	25

DAY 26

HOUR	SKY COVER	CEILING	VIS. WHOLE MILES	VIS. 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	10	2	1		SBS	-02	-03	-12	62	28	26
03	10	2	1		SBS	-01	-02	-10	65	27	25
06	10	2	1		SBS	00	00	-03	88	27	25
09	10	5	0	6	SBS	05	05	03	78	27	23
12	10	10	0	6	BS	10	08	02	70	28	25
15	10	15	2	6	BS	11	10	05	77	27	23
18	10	6	2	6	BS	08	06	-02	63	28	25
21	10	6	5		BS	05	04	-04	66	27	20

DAY 27

HOUR	SKY COVER	CEILING	VIS. WHOLE MILES	VIS. 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	10	11	5		BS	05	04	-04	66	28	21
03	2	UNL	12			01	00	-12	54	27	17
06	3	UNL	12			-02	-03	-14	56	28	16
09	7	UNL	12			00	00	-13	54	28	17
12	0	UNL	12			07	05	-07	52	27	22
15	0	UNL	12			12	10	-02	53	28	20
18	0	UNL	15			10	08	-04	53	28	15
21	0	UNL	15			10	08	-02	58	27	18

DAY 28

HOUR	SKY COVER	CEILING	VIS. WHOLE MILES	VIS. 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	4	UNL	10			07	06	-03	63	30	14
03	0	UNL	12			02	01	-08	62	28	10
06	0	UNL	12			-01	-02	-12	56	28	12
09	10	UNL	15			00	00	-12	56	28	13
12	7	UNL	15			10	08	-02	58	27	17
15	3	UNL	15			15	12	01	54	28	17
18	0	UNL	15			12	10	-01	56	28	12
21	0	UNL	15			08	07	-04	55	28	10

DAY 29

HOUR	SKY COVER	CEILING	VIS. WHOLE MILES	VIS. 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	0	UNL	15			05	03	-07	57	28	11
03	0	UNL	15			02	01	-08	58	30	12
06	0	UNL	15			-01	-02	-13	56	31	10
09	0	UNL	15			-01	-02	-13	56	28	14
12	0	UNL	15			06	04	-06	57	28	14
15	0	UNL	15			11	08	-02	55	27	12
18	0	UNL	15			07	05	-05	57	28	8
21	0	UNL	15			02	01	-07	68	28	8

DAY 30

HOUR	SKY COVER	CEILING	VIS. WHOLE MILES	VIS. 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	0	UNL	15			00	00	-08	66	20	4
03	0	UNL	15			-03	-03	-12	65	24	5
06	3	UNL	15			-02	-02	-11	65	00	0
09	10	200	10			03	02	-05	69	23	5
12	10	100	12			13	11	03	64	25	7
15	10	15	1	6	S	18	15	08	74	23	6
18	10	40	2	6	S	15	14	10	80	27	7
21	6	60	5		S	11	10	06	80	27	5

DAY 31

HOUR	SKY COVER	CEILING	VIS. WHOLE MILES	VIS. 16THS MILE	WEATHER	AIR °F	WET BULB °F	DEW PT. °F	REL. HUM. %	WIND DIR	WIND SPEED KNOTS
00	3	UNL	7			08	08	03	87	28	6
03	0	UNL	10			04	03	-04	68	28	6
06	0	UNL	10			01	00	-07	68	27	6
09	0	UNL	6			02	01	-06	68	30	3
12	3	UNL	12			10	08	-01	61	28	11
15	2	UNL	12			14	11	00	53	28	5
18	3	UNL	12			12	10	-02	53	24	5
21	10	120	12			07	05	-04	60	28	3

STATION: PEORIA ILL

YEAR & MONTH: 78 01

NOTES

CEILING

UNL INDICATES UNLIMITED

WEATHER

- + TORNADO
- T THUNDERSTORM
- Q SQUALL
- R RAIN
- RW RAIN SHOWERS
- ZR FREEZING RAIN
- L DRIZZLE
- ZL FREEZING DRIZZLE
- S SNOW
- SP SNOW PELLETS
- IC ICE CRYSTALS
- SW SNOW SHOWERS
- SG SNOW GRAINS
- IP ICE PELLETS
- A HAIL
- F FOG
- IF ICE FOG
- GF GROUND FOG
- BD BLOWING DUST
- BN BLOWING SAND
- BS BLOWING SNOW
- BY BLOWING SPRAY
- K SMOKE
- H HAZE
- D DUST

WIND

DIRECTIONS ARE THOSE FROM WHICH THE WIND BLOWS. INDICATED IN TENS OF DEGREES FROM TRUE NORTH; I.E., 09 FOR EAST, 18 FOR SOUTH, 27 FOR WEST. ENTRY OF 00 IN THE DIRECTION COLUMN INDICATES CALM.

SPEED IS EXPRESSED IN KNOTS; MULTIPLY BY 1.15 TO CONVERT TO MILES PER HOUR.

U.S. DEPARTMENT OF COMMERCE
NATIONAL CLIMATIC CENTER
FEDERAL BUILDING
ASHEVILLE, N.C. 28801

FEBRUARY 1978
PEORIA, ILLINOIS
NATIONAL WEATHER SERVICE OFC
GREATER PEORIA AIRPORT

Local Climatological Data

MONTHLY SUMMARY

FEBRUARY 1978 PEORIA, ILLINOIS

LATITUDE 40° 40' N LONGITUDE 89° 41' W ELEVATION (GROUND) 652 FT. STANDARD TIME USED: CENTRAL WBAN #14842

Date (1)	Temp. Maximum (2)	Temp. Minimum (3)	Temp. Average (4)	Departure from Normal (5)	Average Dew Point (6)	Heating Degree Days, Base 65° (Season begins with Jul 1) (7A)	Cooling Degree Days (Season begins with Jan 1) (7B)	Weather Types on Dates of Occurrence (8)	Snow, Ice Pellets or Ice on Ground at 06AM In. (9)	Precipitation Water Equivalent In. (10)	Snow, Ice Pellets In. (11)	Avg. Station Pressure In. Elev. 662 Feet m.s.l. (12)	Wind Resultant Dir. (13)	Resultant Speed m.p.h. (14)	Average Speed m.p.h. (15)	Fastest Mile Speed m.p.h. (16)	Fastest Mile Direction (17)	Sunshine Minutes (18)	Percent of Possible (19)	Sky Cover Tenths Sunrise to Sunset (20)	Sky Cover Tenths Midnight to Midnight (21)	Date (22)
1	18	6	12	-13	8	53	0	8	2	.34	.8	29.62	12	5.1	5.9	11	SE	0	0	10	10	1
2	17	8	13	-12	4	52	0	8	3	T	T	29.60	34	6.6	7.1	12	N	493	74	6	8	2
3	20	9	15	-10	5	50	0	8	3	.01	.2	29.80	07	5.6	6.9	7	E	208	34	10	10	3
4	25	14	20	-5	13	45	0	1 6 8	3	.06	.5	29.75	16	6.1	8.3	18	NW	16	3	10	10	4
5	24	-2	11	-15	3	54	0	1 6	3	.02	.3	29.76	32	14.4	14.8	22	N	565	92	1	3	5
6	14	-4	5	-21	- 9	60	0		4	0	0	29.79	33	9.4	10.1	14	N	618	100	0	0	6
7	20	-7	7	-19	- 3	58	0		4	0	0	29.74	35	6.8	8.9	10	N	382	63	10	7	7
8	23	5	14	-12	6	51	0	8	4	T	T	29.67	03	5.8	7.1	10	NE	387	59	7	7	8
9	25	3	14	-12	10	51	0	1 8	3	0	0	29.62	02	6.7	7.5	10	N	1	0	10	9	9
10	28	8	18	-8	11	47	0	8	3	T	T	29.40	31	4.4	5.5	9	NW	315	50	6	6	10
11	27	3	15	-12	8	50	0	8	3	0	0	29.44	23	1.9	3.9	6	S	115	18	8	8	11
12	29	22	26	-1	18	38	0	8	3	0	0	29.41	05	5.5	6.5	13	NE	0	0	10	10	12
13	29	23	26	-1	18	39	0	8 9	3	.38	4.5	29.02	05	17.0	17.7	23	N	0	0	10	10	13
14	29	15	22	-5	13	43	0		8	T	T	29.34	33	6.4	8.8	15	N	488	78	9	10	14
15	23	4	14	-14	10	51	0	8	8	.01	.1	29.43	28	7.7	8.1	15	W	57	9	10	8	15
16	18	-7	6	-22	- 5	59	0	1	8	0	0	29.48	25	5.7	6.5	14	W	627	97	1	1	16
17	15	-5	5*	-23	- 6	60	0	8	6	0	0	29.55	27	6.7	7.1	10	NW	648	100	1	1	17
18	19	-6	7	-21	- 5	58	0		5	T	T	29.47	28	6.6	6.8	10	NW	548	85	1	0	18
19	18	-7	6	-23	- 3	59	0	2 8	5	0	0	29.39	18	4.5	5.8	11	S	580	89	1	2	19
20	24	8	17	-12	9	48	0	8	5	T	T	29.22	08	4.2	8.1	10	N	35	5	10	9	20
21	23	5	14	-15	4	51	0	8	4	0	0	29.48	32	9.1	10.1	12	W	642	98	1	1	21
22	22	-7*	8	-21	1	57	0	6 8	4	.01	.1	29.40	17	9.3	10.6	20	S	305	46	9	7	22
23	28	22	25	-5	18	40	0	1 6 8	4	T	T	29.21	27	8.0	12.8	19	W	150	22	9	9	23
24	41*	16	29*	-1	19	36	0		3	0	0	29.14	22	10.9	12.5	22	S	488	75	6	6	24
25	29	18	24	-6	17	41	0		3	T	T	29.35	29	17.6	17.8	29	NW	98	15	8	8	25
26	25	8	17	-14	7	48	0		3	0	0	29.60	29	7.5	8.1	18	NW	668	100	2	1	26
27	29	11	20	-11	12	45	0	8	3	T	T	29.47	18	7.8	7.9	15	S	0	0	10	10	27
28	32	22	27	-4	21	38	0	8	2	.06	.7	29.34	05	2.4	6.2	13	N	0	0	10	10	28

Weather types: 1 FOG, 2 HEAVY FOG, 3 THUNDERSTORM, 4 ICE PELLETS, 5 HAIL, 6 GLAZE, 7 DUSTSTORM, 8 SMOKE, HAZE, 9 BLOWING SNOW

	Max.	Min.	Avg.	Dep.	Dew Pt.	Heating DD	Cooling DD
SUM / TOTAL	672	198				1383	0
AVG. / DEP.	24.0	8.7	15.4	-12.3	7	339	0
SEASON TO DATE TOTAL						5479	0
SEASON TO DATE DEP.						880	0

NUMBER OF DAYS	
Maximum Temp. ≥ 90°	0
Maximum Temp. ≤ 32°	27
Minimum Temp. ≤ 32°	28
Minimum Temp. ≤ 0°	9
Precipitation ≥ .01 inch	9
Snow, ice pellets ≥ 1.0 inch	1
Thunderstorms	0
Heavy fog	1
Clear 8	Partly cloudy 4	Cloudy 16

Precipitation total	Snow, ice pellets total	Station pressure	Resultant dir.	Resultant speed	Average speed	Fastest mile speed	Fastest mile dir.	Sunshine total	%	Sky cover S-S sum	Sky cover M-M sum
.59	7.0	29.49	31	2.5	8.8	29	NW	8400		187	181
DEP. -0.81						DATE: 25		Possible 17907	For month 47	AVG. 6.7	AVG. 6.5

Greatest in 24 hours and dates: Precipitation	Date	Snow, ice pellets	Date	Greatest depth on ground of snow, ice pellets or ice	Date
.38	13	4.5	13	9	14+

* EXTREME FOR THE MONTH - LAST OCCURRENCE IF MORE THAN ONE.
T TRACE AMOUNT
+ ALSO ON AN EARLIER DATE, OR DATES.
HEAVY FOG: - VISIBILITY 1/4 MILE OR LESS.
FIGURES FOR WIND DIRECTIONS ARE TENS OF DEGREES CLOCKWISE FROM TRUE NORTH. 00 = CALM.
DATA IN COLS. 6 AND 12-15 ARE BASED ON 7 OR MORE OBSERVATIONS PER DAY AT 3-HOUR INTERVALS.
FASTEST MILE WIND SPEEDS ARE FASTEST OBSERVED ONE-MINUTE VALUES WHEN DIRECTIONS ARE IN TENS OF DEGREES. THE / WITH THE DIRECTION INDICATES PEAK GUST SPEED.
ANY ERRORS DETECTED WILL BE CORRECTED AND CHANGES IN SUMMARY DATA WILL BE ANNOTATED IN THE ANNUAL SUMMARY.

SUMMARY BY HOURS

Hour Local Time	Sky Cover Tenths	Station Pressure In.	Air °F	Wet Bulb °F	Dew Pt. °F	Relative Humidity %	Wind Speed m.p.h.	Resultant Wind Direction	Resultant Wind Speed m.p.h.
00	6	29.48	15	13	6	70	7.3	31	2.7
03	6	29.48	12	11	5	71	7.4	33	3.1
06	6	29.48	11	10	3	70	7.7	32	2.9
09	6	29.51	14	13	6	68	8.8	34	2.3
12	7	29.50	21	18	9	61	10.6	29	2.2
15	7	29.47	23	20	10	60	11.8	30	3.1
18	7	29.47	20	17	10	65	9.0	30	2.3
21	6	29.48	18	19	9	70	7.9	30	2.2

HOURLY PRECIPITATION (WATER EQUIVALENT IN INCHES)

Date	A.M. 1	2	3	4	5	6	7	8	9	10	11	12	P.M. 1	2	3	4	5	6	7	8	9	10	11	12	Date
1												T	.01	.01	T	T	T	T		T	.01	.01	T	T	1
2	T	T		T	T	T	T	T	T																2
3									T	.01	T	T	T	T	T	T		T	T	T	T	T	T	T	3
4									T				.01	.02	.01	T	T	T	.01	T	.01	T	T	T	4
5	T	T	.01	T	T	T	T	.01																	5
6																									6
7																									7
8					T	T	T	T	T	T															8
9																									9
10								T	T	T	T	T													10
11																									11
12																									12
13		T	T	.01	.01	.02	.05	.07	.04	.05	.02	.04	.01	.01	T	T	T	.01	.03	.01	T	T			13
14																					T	T	T	T	14
15	T	T	T	T	T	T	T	T	T	T	.01	T			T	T	T								15
16																									16
17																									17
18																T	T								18
19																									19
20													T	T	T	T	T	T	T	T	T				20
21																									21
22																			T	.01	T	T	T	T	22
23	T	T	T	T	T	T	T	T	T	T															23
24																									24
25												T	T												25
26																									26
27							T	T	T																27
28		T	T	T	T	T	T								T	T	T	.01	.01	.02	.01	.01	T	T	28

SUBSCRIPTION PRICE: $2.55 PER YEAR. FOREIGN MAILING $1.85 EXTRA. SINGLE COPY: 20 CENTS FOR MONTHLY ISSUE. 20 CENTS FOR ANNUAL SUMMARY. OTHER DATA IN RECORDS ON FILE CAN BE FURNISHED AT COST VIA MICROFILM, MICROFICHE, OR PAPER COPIES OF ORIGINAL RECORDS. MAKE CHECKS PAYABLE TO DEPARTMENT OF COMMERCE, NOAA. SEND PAYMENTS, ORDERS, AND INQUIRIES TO NATIONAL CLIMATIC CENTER, FEDERAL BUILDING, ASHEVILLE, NORTH CAROLINA 28801.

I CERTIFY THAT THIS IS AN OFFICIAL PUBLICATION OF THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, AND IS COMPILED FROM RECORDS ON FILE AT THE NATIONAL CLIMATIC CENTER, ASHEVILLE, NORTH CAROLINA 28801.

noaa NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION / ENVIRONMENTAL DATA SERVICE

Daniel B. Mitchell
DIRECTOR, NATIONAL CLIMATIC CENTER

USCOMM--NOAA--ASHEVILLE 03/20/78 400

OBSERVATIONS AT 3-HOUR INTERVALS

Day	Hour	Sky cover (tenths)	Ceiling (hds. of ft.)	Visibility: whole miles	Visibility: 16ths mile	Weather	Temp. dry bulb °F	Temp. wet bulb °F	Temp. dew pt. °F	Rel. hum. %	Wind dir	Wind speed knots
01	00	10	100	12			08	05	-02	68	00	0
01	03	10	110	10			08	08	02	73	17	3
01	06	10	90	10			12	10	02	64	09	4
01	09	10	60	7			14	12	08	70	11	6
01	12	10	90	7		S	18	16	08	65	14	6
01	15	10	30	1	8	SW	18	17	11	74	12	6
01	18	10	100	6			17	16	11	77	12	5
01	21	10	30	5		S	18	15	11	81	08	4
02	00	10	20	4		S	18	15	11	81	00	0
02	03	10	21	7			13	12	08	84	34	4
02	06	10	13	5		S	14	13	08	80	34	10
02	09	5	UNL	5		H	11	10	04	73	33	8
02	12	6	UNL	5		H	14	12	03	81	32	6
02	15	6	UNL	6		H	15	13	03	90	33	5
02	18	7	UNL	6		H	08	07	-03	90	30	5
02	21	6	250	10			08	08	-02	63	03	5
03	00	10	75	10			10	08	00	64	02	6
03	03	10	79	10			10	08	00	64	02	6
03	06	10	30	10			10	08	-01	61	09	6
03	09	10	39	2	8	S	12	10	01	61	11	6
03	12	10	90	6		H	16	14	08	71	15	3
03	15	6	39	7		S	19	17	10	68	09	6
03	18	10	14	2	8	SW	18	16	10	71	06	6
03	21	10	30	6		SW	15	14	08	77	07	6
04	00	10	20	6			14	13	08	80	08	5
04	03	10	23	7			15	15	10	80	06	5
04	06	10	7	6		F	14	13	08	90	17	5
04	09	10	26	3		H	15	14	10	80	13	6
04	12	10	20	2	8	H	21	19	13	71	16	10
04	15	10	25	1		SW	22	21	16	79	16	6
04	18	10	4	1		ZLH	22	21	17	81	16	8
04	21	10	1	0	12	ZLF	23	22	18	89	22	6
05	00	10	13	3		SF	24	22	17	75	30	15
05	03	10	20	1	8	SF	20	18	13	74	31	13
05	06	10	30	3		SF	18	16	10	71	33	14
05	09	0	UNL	12			12	10	01	61	33	16
05	12	0	UNL	15			13	11	01	58	34	15
05	15	0	UNL	15			14	12	01	56	32	14
05	18	0	UNL	15			10	07	-06	48	31	8
05	21	0	UNL	15			-01	-02	-11	62	30	6
06	00	0	UNL	15			-02	-03	-12	62	31	10
06	03	0	UNL	15			00	00	-13	54	36	6
06	06	0	UNL	15			-03	-04	-16	53	30	6
06	09	0	UNL	15			01	00	-13	51	35	12
06	12	0	UNL	15			10	08	-09	50	32	9
06	15	0	UNL	15			14	11	00	53	35	10
06	18	0	UNL	15			08	07	-02	61	32	7
06	21	0	UNL	15			03	02	-07	63	32	6
07	00	0	UNL	15			00	00	-10	62	35	6
07	03	0	UNL	15			00	00	-10	62	35	7
07	06	0	UNL	15			-02	-03	-12	62	30	5
07	09	10	UNL	12			03	02	-07	63	34	6
07	12	10	UNL	12			17	14	02	51	35	6
07	15	10	20	15			18	16	04	52	34	7
07	18	10	250	15			15	13	07	70	34	6
07	21	6	UNL	15			12	11	06	77	30	5
08	00	10	20	15			08	08	03	78	34	5
08	03	6	20	15			08	08	03	78	36	5
08	06	10	24	15		SW	11	10	05	77	35	4
08	09	10	23	7		S	15	14	08	74	02	4
08	12	10	UNL	10			23	18	11	63	03	7
08	15	1	UNL	12			21	18	07	55	08	10
08	18	7	UNL	12			14	12	08	70	06	6
08	21	3	UNL	12			10	08	05	80	36	6
09	00	2	UNL	12			07	06	02	80	02	5
09	03	2	UNL	2	8	F	08	08	03	76	36	7
09	06	10	18	5		F	13	12	08	80	36	6
09	09	10	18	6		H	20	18	12	71	04	4
09	12	10	23	5			24	21	13	63	04	11
09	15	10	23	6			25	22	13	60	06	8
09	18	10	22	12			23	21	15	71	34	6
09	21	10	18	12			23	21	15	71	36	5
10	00	10	25	12			21	18	14	74	31	4
10	03	10	25	12			21	18	14	74	34	4
10	06	10	25	12			21	18	13	71	32	4
10	09	10	25	7		S	21	18	12	68	01	5
10	12	6	100	10			25	21	10	53	35	6
10	15	0	UNL	12			25	21	10	53	20	6
10	18	10	100	12			22	18	08	57	20	3
10	21	2	UNL	15			12	11	05	73	28	4
11	00	2	UNL	15			11	10	04	73	05	4
11	03	0	UNL	10			04	03	-02	76	20	4
11	06	0	UNL	7			03	02	-05	68	20	4
11	09	6	UNL	4		KH	15	14	08	74	00	0
11	12	10	80	6		H	24	21	13	63	23	6
11	15	9	UNL	7			27	23	12	53	24	3
11	18	10	45	10			26	23	15	63	17	6
11	21	10	42	10			25	22	15	68	00	0
12	00	10	50	10			25	22	15	66	00	0
12	03	10	40	7			24	22	15	66	03	5
12	06	10	40	7			23	21	14	68	23	3
12	09	10	40	4		H	25	22	15	66	05	7
12	12	10	40	4		H	27	24	15	61	27	6
12	15	10	60	6		H	28	25	15	56	07	6
12	18	10	60	6		H	28	25	17	63	05	7
12	21	10	65	6		H	27	24	18	68	05	6
13	00	10	55	6		H	27	24	18	68	05	6
13	03	10	15	3		S	26	23	16	66	07	16
13	06	10	6	0	8	SBS	24	22	17	75	08	16
13	09	10	4	0	8	SBS	23	22	18	81	09	18
13	12	10	4	0	8	SBS	25	23	18	78	09	20
13	15	10	15	5		SBS	26	24	18	75	04	18
13	18	10	12	1	8	SBS	27	25	18	72	02	14
13	21	10	11	5		SBS	28	26	21	75	02	12
14	00	10	13	7			28	27	21	72	01	12
14	03	10	20	12			25	23	16	68	35	11
14	06	10	24	12			21	18	12	68	36	9
14	09	7	UNL	12			17	15	07	65	34	6
14	12	10	250	15			25	21	11	55	20	4
14	15	10	UNL	15			28	24	13	53	20	7
14	18	10	UNL	15			22	18	11	62	20	6
14	21	10	31	15			22	20	12	65	24	6
15	00	10	28	12		S	22	20	13	68	23	4
15	03	10	25	6		S	23	21	15	71	26	7
15	06	10	35	10		S	20	18	13	74	30	6
15	09	10	20	3		S	20	18	12	71	27	6
15	12	10	20	7			21	18	10	62	25	10
15	15	10	18	10		S	18	16	07	62	26	13
15	18	5	UNL	7			14	12	03	61	26	4
15	21	3	UNL	12			11	10	03	70	27	4
16	00	1	UNL	15			04	03	-08	63	20	3
16	03	0	UNL	12			-02	-03	-12	62	00	0
16	06	0	UNL	12			-04	-04	-14	61	23	3
16	09	0	UNL	4		F	03	02	-04	72	18	3
16	12	4	UNL	7			15	12	01	54	22	12
16	15	0	UNL	10			17	14	04	56	27	12
16	18	1	UNL	10			12	10	05	66	26	5
16	21	1	UNL	12			08	04	-09	60	20	4
17	00	0	UNL	15			02	01	-07	68	20	4
17	03	0	UNL	15			00	00	-08	65	26	7
17	06	0	UNL	15			-02	-02	-10	68	25	4
17	09	0	UNL	6		H	01	00	-08	68	20	5
17	12	3	UNL	10			11	08	-03	53	26	6
17	15	3	UNL	12			15	12	-01	48	30	11
17	18	2	UNL	12			10	08	-02	58	20	6
17	21	0	UNL	15			04	03	-08	57	20	6
18	00	0	UNL	15			01	00	-08	65	20	5
18	03	0	UNL	15			00	00	-08	55	30	5
18	06	0	UNL	10			-08	-08	-17	58	30	6
18	09	0	UNL	7			02	01	-08	62	30	6
18	12	0	UNL	7			13	11	01	58	30	6
18	15	0	UNL	10			18	16	05	57	28	6
18	18	0	UNL	10			18	12	04	64	27	5
18	21	0	UNL	12			08	05	-04	63	27	4
19	00	0	UNL	10			03	02	-04	72	26	3
19	03	0	UNL	4		KH	-05	-05	-13	68	00	0
19	06	4	UNL	2		KH	-04	-04	-13	65	20	3
19	09	2	UNL	1	8	FH	-01	-01	-06	72	27	3
19	12	1	UNL	4		H	13	11	02	61	16	3
19	15	1	UNL	7		H	17	14	05	56	17	5
19	18	1	UNL	7			14	12	05	67	16	6
19	21	8	40	7			12	11	05	73	15	7
20	00	3	UNL	7			13	12	05	70	16	6
20	03	10	37	6			11	10	04	73	13	6
20	06	10	40	7			13	12	06	73	13	6
20	09	7	UNL	6		H	17	15	08	68	12	6
20	12	10	30	7			21	18	10	62	13	6
20	15	10	100	3		SW	23	20	13	65	04	6
20	18	10	100	5		SW	20	18	12	71	02	7
20	21	10	250	10			18	17	11	74	36	6
21	00	10	35	7			19	17	10	68	36	5
21	03	0	UNL	4		H	09	08	02	73	36	7
21	06	0	UNL	5		H	05	04	-03	68	31	6
21	09	0	UNL	6			11	09	01	64	33	6
21	12	0	UNL	6			21	18	07	55	32	10
21	15	5	UNL	12			23	20	10	57	26	12
21	18	3	UNL	7			18	14	04	56	31	6
21	21	3	UNL	15			08	07	-03	58	20	7
22	00	0	UNL	15			08	05	-03	66	20	6
22	03	0	UNL	7			01	00	-07	68	25	3
22	06	0	UNL	7			-08	-08	-16	61	20	4
22	09	10	UNL	4		H	04	03	-04	68	15	4
22	12	10	250	6			16	14	05	63	17	13
22	15	10	250	15			21	18	08	60	15	15
22	18	10	15	10			21	18	10	62	16	15
22	21	10	20	5		ZLS	22	20	15	74	15	13
23	00	10	7	5		S	22	21	16	76	16	13
23	03	10	4	2		F	22	21	18	85	17	15
23	06	10	4	2		SF	23	22	18	81	25	9
23	09	10	6	2	8	SF	23	22	18	81	26	6
23	12	6	18	6			23	22	17	78	30	14
23	15	8	20	6			27	24	16	63	30	15
23	18	10	20	10			28	25	16	61	30	14
23	21	5	UNL	10			23	21	14	68	22	7
24	00	5	UNL	12			24	21	14	66	24	6
24	03	2	UNL	15			20	18	12	71	21	6
24	06	7	120	15			18	17	14	74	18	7
24	09	10	UNL	12			28	24	17	65	17	10
24	12	7	UNL	12			38	31	21	51	21	15
24	15	6	UNL	12			40	34	24	53	23	16
24	18	7	250	10			39	32	26	59	20	10
24	21	6	250	10			34	31	26	73	24	6
25	00	10	33	10			35	31	25	67	27	14
25	03	10	27	15			30	26	17	58	28	20
25	06	10	20	15			27	24	18	63	30	18
25	09	10	18	15			26	23	15	63	28	14
25	12	10	19	7		S	28	23	18	68	30	15
25	15	10	18	10			28	25	17	63	28	15
25	18	4	UNL	10			28	23	15	63	28	14
25	21	10	22	10			23	20	13	66	28	14
26	00	1	UNL	10			18	17	08	65	28	12
26	03	0	UNL	15			13	12	05	70	30	10
26	06	0	UNL	15			10	08	03	73	30	7
26	09	0	UNL	15			13	11	04	67	33	6
26	12	5	UNL	15			23	20	10	57	25	5
26	15	3	UNL	15			25	21	08	50	28	6
26	18	3	UNL	12			22	18	10	60	26	4
26	21	0	UNL	12			17	16	07	66	26	4
27	00	0	UNL	12			12	11	05	73	00	0
27	03	7	65	7			14	13	07	74	00	0
27	06	10	40	6		H	17	16	10	74	18	5
27	09	10	80	6			22	20	12	66	17	10
27	12	10	80	6			28	23	15	63	18	10
27	15	10	90	6			28	25	16	58	15	11
27	18	10	55	10			28	25	17	63	15	10
27	21	10	55	12			27	24	17	66	16	6
28	00	10	17	10			28	25	18	66	17	6
28	03	10	5	2		S	27	25	20	75	17	5
28	06	10	11	2		SW	27	25	20	75	16	6
28	09	10	5	2	8	H	28	26	21	75	15	4
28	12	10	12	5		H	31	28	22	68	35	7
28	15	10	14	5		SW	31	28	22	68	02	6
28	18	10	7	2	12	SW	28	27	22	75	02	6
28	21	10	6	2		SW	28	24	18	75	01	11

NOTES

CEILING
UNL INDICATES UNLIMITED

WEATHER

- T TORNADO
- T THUNDERSTORM
- Q SQUALL
- R RAIN
- RW RAIN SHOWERS
- ZR FREEZING RAIN
- L DRIZZLE
- ZL FREEZING DRIZZLE
- S SNOW
- SP SNOW PELLETS
- IC ICE CRYSTALS
- SW SNOW SHOWERS
- SG SNOW GRAINS
- IP ICE PELLETS
- A HAIL
- F FOG
- IF ICE FOG
- GF GROUND FOG
- BD BLOWING DUST
- BN BLOWING SAND
- BS BLOWING SNOW
- BY BLOWING SPRAY
- K SMOKE
- H HAZE
- D DUST

WIND

DIRECTIONS ARE THOSE FROM WHICH THE WIND BLOWS, INDICATED IN TENS OF DEGREES FROM TRUE NORTH; I.E., 09 FOR EAST, 18 FOR SOUTH, 27 FOR WEST. ENTRY OF 00 IN THE DIRECTION COLUMN INDICATES CALM.

SPEED IS EXPRESSED IN KNOTS; MULTIPLY BY 1.15 TO CONVERT TO MILES PER HOUR.

STATION: PEORIA ILL

YEAR & MONTH: 78 02

U.S. DEPARTMENT OF COMMERCE
NATIONAL CLIMATIC CENTER
FEDERAL BUILDING
ASHEVILLE, N.C. 28801

AN EQUAL OPPORTUNITY EMPLOYER

POSTAGE AND FEES PAID
U.S. DEPARTMENT OF COMMERCE
COM-210

FIRST CLASS

APPENDIX F

KANKAKEE RIVER OPERATION MAP

This Appendix presents a map of the Kankakee River which provides an operational summary of LACV-30 icebreaking efforts for flood control in that area.

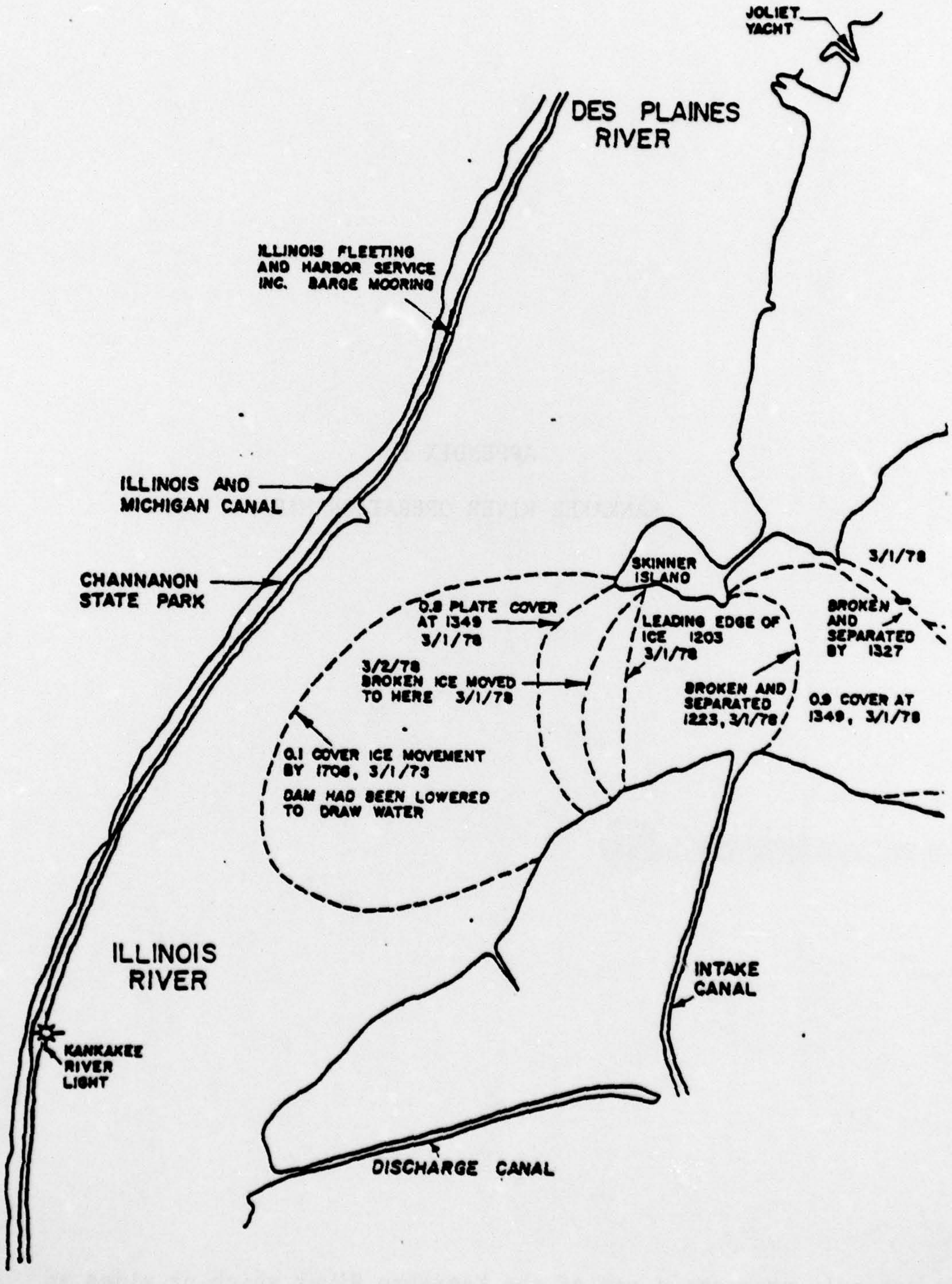


Figure F-1a   Kankakee River Operation

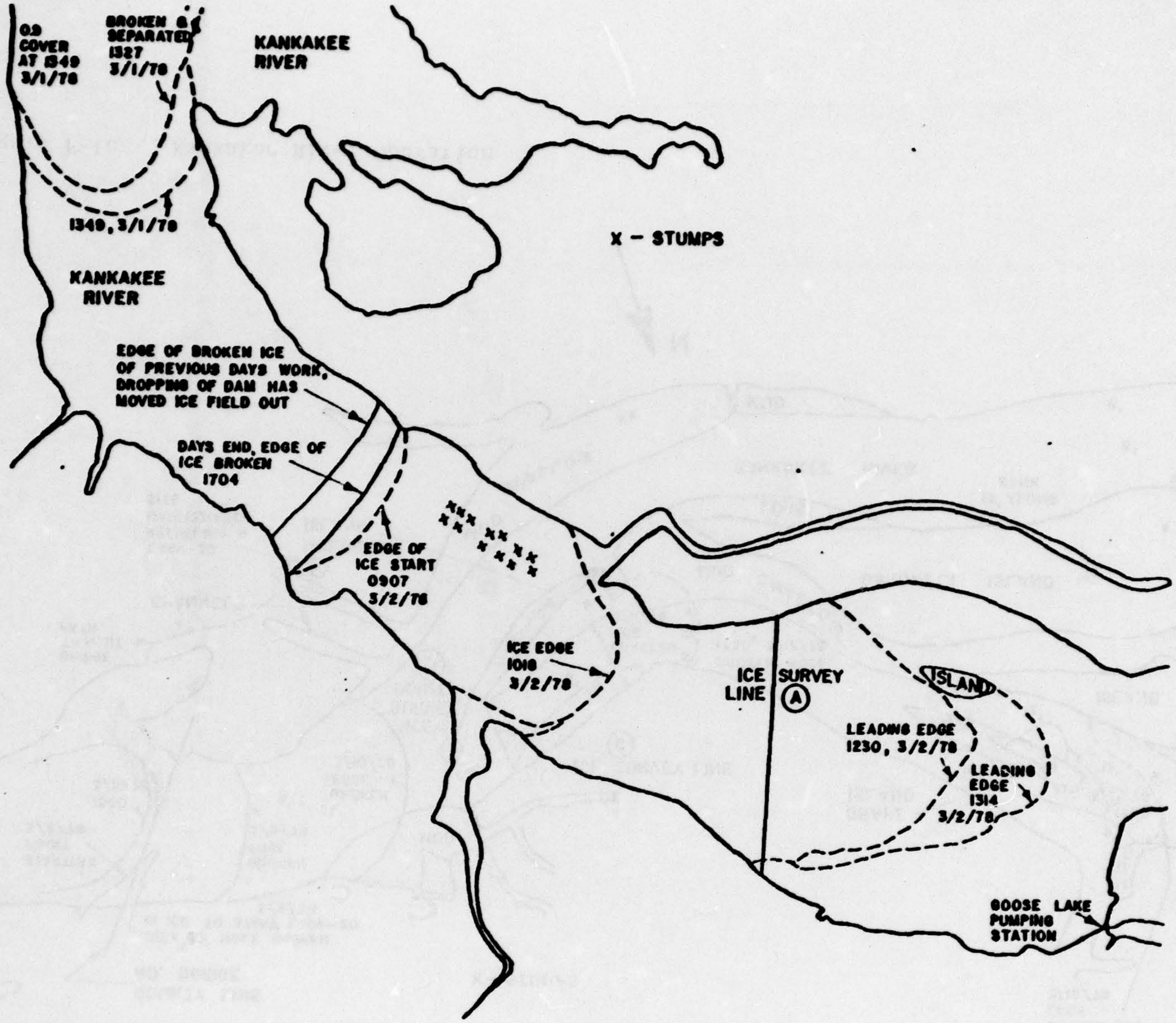


Figure F-1b Kankakee River Operation

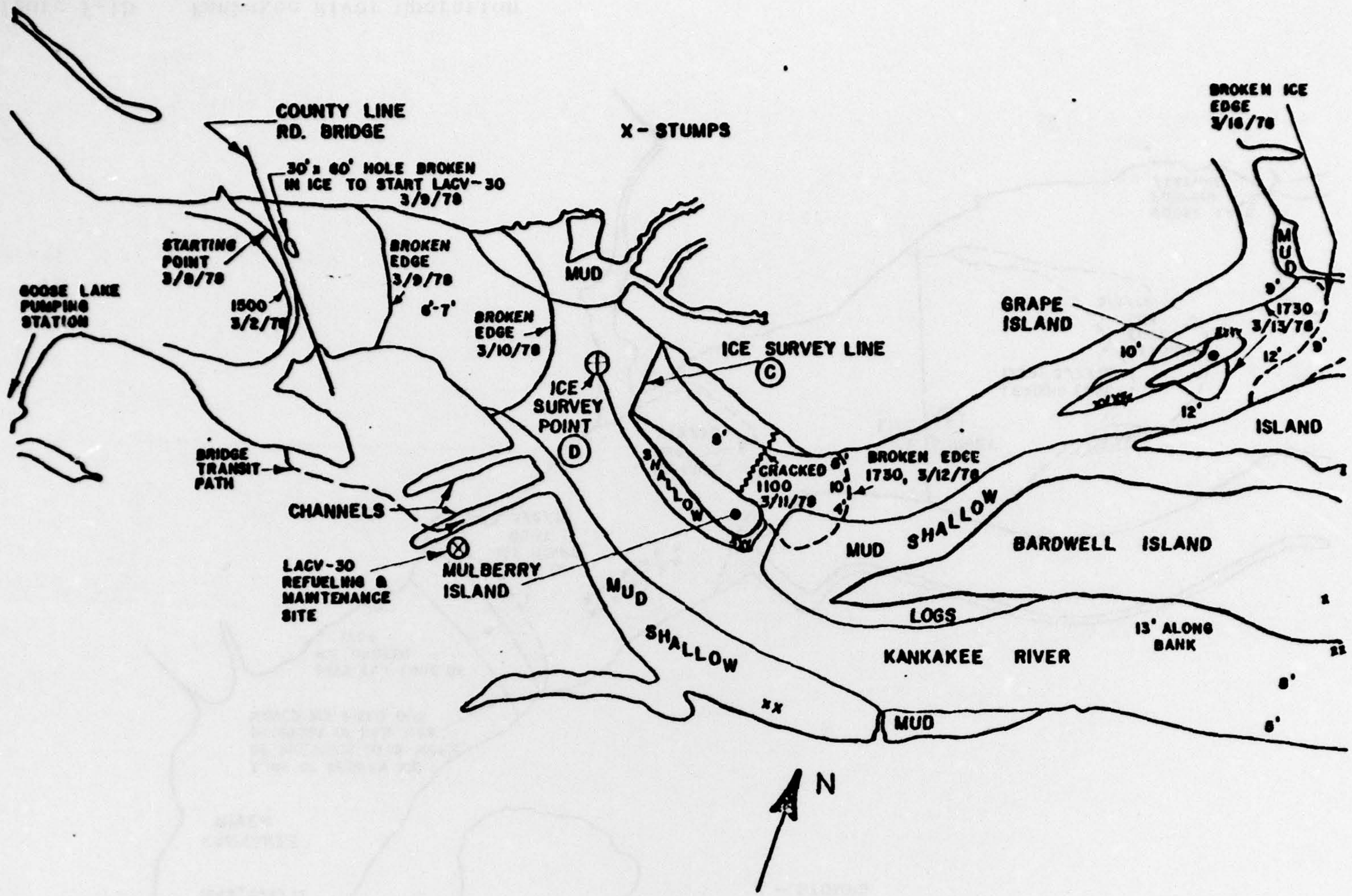


Figure F-1c Kankakee River Operation